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(54) **An exhaust purification device of an engine**

Abgasreinigungsvorrichtung für Brennkraftmaschine

Dispositif d'épuration de gaz d'échappement pour moteurs à combustion interne

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- **PATENT ABSTRACTS OF JAPAN vol. 018, no. 691 (M-1731), 26 December 1994 & JP 06 272546 A (TOYOTA MOTOR CORP), 27 September 1994,**
- **PATENT ABSTRACTS OF JAPAN vol. 94, no. 010 & JP 06 280550 A (TOYOTA MOTOR CORP), 4 October 1994,**
- **PATENT ABSTRACTS OF JAPAN vol. 018, no. 691 (M-1731), 26 December 1994 & JP 06 272540 A (TOYOTA MOTOR CORP), 27 September 1994,**

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an exhaust purification device of an engine.

2. Description of the Related Art

[0002] An internal combustion engine has been developed which provides in the engine exhaust passage an NO_x absorbent which absorbs NO_x when the air-fuel ratio of the inflowing exhaust gas is lean and releases the absorbed NO_x when the air-fuel ratio of the inflowing exhaust gas becomes rich, which estimates the amount of NO_x absorbed in the NO_x absorbent from the engine operating state, and, when the amount of NO_x estimated to be absorbed in the NO_x absorbent exceeds a predetermined set value, changes the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent from lean to rich to make the NO_x be released from the NO_x absorbent.

[0003] This estimated amount of absorption of NO_x, however, does not always coincide with the actual amount of absorption of NO_x, that is, sometimes will be smaller or larger than the actual amount of absorption of NO_x. Accordingly, where the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent is changed from lean to rich when the estimated amount of absorption of NO_x exceeds the predetermined set value, if the estimated amount of absorption of NO_x is smaller than the actual amount of absorption of NO_x, the ability of absorption of the NO_x absorbent is saturated before the estimated amount of NO_x reaches the set value, so there arises a problem in that the NO_x is not absorbed into the NO_x absorbent but is released into the atmosphere. In contrast, if the estimated amount of absorption of NO_x is larger than the actual amount of absorption of NO_x, the air-fuel ratio is made rich when the amount of NO_x, absorbed in the NO_x absorbent is still small, and therefore the frequency of the air-fuel ratio being made rich becomes high, and thus there arises a problem that the amount of fuel consumption is increased.

[0004] From document EP-A-0 636 770 an exhaust purification device of an engine is known comprising an NOx absorbent disposed in the exhaust passage of the engine for absorbing NOx when the air-fuel ratio of the exhaust gas flowing into the absorbent is lean while discharging NOx from the absorbent when the air-fuel ratio of the exhaust gas flowing into the absorbent becomes stoichiometric or rich. An air-fuel ratio sensor is disposed downstream of the NOx absorbent for judging that the discharge of NOx from the absorbent is completed when the air-fuel ratio detected by the sensor has been switched from lean to rich after the air-fuel ratio of the exhaust gas flowing into the absorbent has been switched from lean to rich. The NOx amount absorbed in the absorbent can be estimated from the lean operation time.

[0005] Documents JP 06280550 A and JP 06272540 A disclose a similar exhaust purification device comprising an NOx absorbent. According to these documents, the amount of NOx absorbed by the NOx absorbent can be calculated or estimated from the operating conditions of the engine. The NOx releasing is controlled on the basis of said estimation, wherein NOx is released when the estimated NOx amount is higher than a limit value.

SUMMARY OF THE INVENTION

[0006] The object underlying the invention is to provide an exhaust gas purification device capable of effectively preventing the release of NOx into the atmosphere and improving the fuel consumption.

[0007] This object is solved by the features of claim 1. The exhaust purification device of the invention comprises an NOx absorbent capable of absorbing NOx and releasing NOx. Furthermore, an NOx amount calculation means is provided for calculating an entire amount of NOx stored in the NOx absorbent, and a correction value calculating means is provided for calculating a correction value for said estimated amount of NOx to ensure that said estimated amount of NOx is correct.

[0008] The correction is made on the basis of the calculated amount of NOx so that the estimated amount of NOx represents the actual amount of absorption of NOx. When this corrected amount of NOx reaches a set value, the action of releasing the NOx from the NOx absorbent is carried out.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention may be more fully understood from the description of the preferred embodiments of the invention set forth below with reference to the accompanying drawings, wherein:

Fig. 1 is an overall view of an engine;
Fig. 2 is a view of a map of a basic fuel injection time;
Fig. 3 is a view of a correction coefficient K;
Fig. 4 is a graph schematically showing a concentration of unburnt HC and CO and oxygen in exhaust gas discharged from the engine;
Figs. 5A and 5B are views for explaining an absorption and releasing action of NO_x;
Fig. 6 is a view of an amount of absorption of NO_x NOXA;
Fig. 7 is a time chart of the air-fuel ratio control;
Figs. 8A and 8B are views of a cycle of making the air-fuel ratio of an air-fuel mixture rich for releasing NO_x and a rich time at this time;
Fig. 9 is a view of a current flowing between an anode and a cathode of an O_2 sensor;
Figs. 10 and 11 are time charts showing the change

of the value of a current flowing between the anode and cathode of the NO_x sensor;

Figs. 12 and 13 are flow charts of the control of the air-fuel ratio;

Fig. 14 is a flow chart of a feedback control I;

Fig. 15 is a time chart of the change of a feedback correction coefficient FAF;

Fig. 16 is a flow chart of a feedback control II;

Fig. 17 is a flow chart of processing for release of NO_x;

Fig. 18 is a flow chart of a decision of deterioration;

Figs. 19A and 19B are views of a cycle TL for making the air-fuel ratio of the air-fuel mixture rich for releasing NO_x and the rich time TR;

Figs. 20 and 21 are flow charts of another embodiment for controlling the air-fuel ratio;

Fig. 22 is a flow chart for the processing for release of NO_x; and

Fig. 23 is a flow chart of a decision of deterioration.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] Referring to Fig. 1, 1 denotes an engine body, 2, a piston, 3, a combustion chamber, 4, a spark plug, 5, an intake valve, 6, an intake port, 7, an exhaust valve, and 8, an exhaust port. The intake port 6 is connected to a surge tank 10 via a corresponding branch pipe 9, and a fuel injector 11 injecting fuel toward the interior of the input port 6 is attached to each branch pipe 9. The surge tank 10 is connected via an intake duct 12 to an air cleaner 13, and a throttle valve 14 is arranged in the intake duct 12. On the other hand, the exhaust port 8 is connected via an exhaust manifold 15 and an exhaust pipe 16 to a casing 17 containing a NO_x absorbent 18.

[0011] An electronic control unit 30 comprises a digital computer and is provided with a read only memory (ROM) 32, a random access memory (RAM) 33, a microprocessor (CPU) 34, a back-up RAM 35 continuously connected to a power source, an input port 36, and an exhaust port 37 - all of which are connected to each other by a bi-directional bus 31. In the surge tank 10, a pressure sensor 19 for generating an output voltage proportional to an absolute pressure in the surge tank 10 is arranged. The output voltage of this pressure sensor 19 is input to the input port 36 via a corresponding analog-to-digital (AD) converter 38. An air-fuel ratio sensor (hereinafter referred to as an O_2 sensor) 20 is arranged in the exhaust manifold 15, and the output of this O_2 sensor 20 is input to the input port 36 via the corresponding AD converter 38. Another air-fuel ratio sensor (hereinafter referred to as an O_2 sensor) 22 is arranged in the exhaust pipe 21 downstream of the NO_x absorbent 18. This O_2 sensor 22 is connected to the input port 36 via a corresponding AD converter 38. Further, an engine speed sensor 23 generating an output pulse representing the engine speed and a vehicle speed sensor 24 generating an output pulse representing the vehicle speed are connected to the input port 36. On the other hand, the output port 37 is connected via the corresponding drive circuit 39 to the spark plug 4, fuel injection valve 11, and the alarm lamp 25.

[0012] In the engine shown in Fig. 1, a fuel injection time TAU is calculated on the basis of for example the following equation:

$$TAU = TP \circ K \circ FAF$$

[0013] Here, TP represents a basic fuel injection time, K, a correction coefficient, and FAF, a feedback correction coefficient, respectively. The basic fuel injection time TP indicates a fuel injection time necessary for making the air-fuel ratio of the air-fuel mixture to be supplied into the engine cylinder the stoichiometric air-fuel ratio. This basic fuel injection time TP is found in advance by experiments and preliminarily stored in the ROM 32 in the form of a map as shown in Fig. 2 as a function of the absolute pressure PM in the surge tank 10 and the engine rotation speed N. The correction coefficient K is a coefficient for controlling the air-fuel ratio of the air-fuel mixture to be supplied into the engine cylinder. If K = 1.0, the air-fuel ratio of the air-fuel mixture to be supplied into the engine cylinder becomes the stoichiometric air-fuel ratio. Contrary to this, when K becomes smaller than 1.0, the air-fuel ratio of the air-fuel mixture to be supplied into the engine cylinder becomes larger than the stoichiometric air-fuel ratio, that is, lean, and when K becomes larger than 1.0, the air-fuel ratio of the air-fuel mixture supplied into the engine cylinder becomes smaller than the stoichiometric air-fuel ratio, that is, rich.

[0014] The feedback correction coefficient FAF is a coefficient for making the air-fuel ratio accurately coincide with the stoichiometric air-fuel ratio on the basis of the output signal of the O_2 sensor 20 when K = 1.0, that is, when the air-fuel ratio of the air-fuel mixture supplied into the engine cylinder should be made the stoichiometric air-fuel ratio. This feedback correction coefficient FAF moves up or down around about 1.0. The FAF is decreased when the air-fuel mixture becomes rich and increased when the air-fuel mixture becomes lean. Note that, when K < 1.0 or K > 1.0, the FAF is fixed to 1.0.

[0015] The target air-fuel ratio of the air-fuel mixture which should be supplied into the engine cylinder, that is, the value of the correction coefficient K, is changed in accordance with the operating state of the engine. In the embodiment according to the present invention, basically, as shown in Fig. 3, it is determined in advance as a function of the absolute pressure PM in the surge tank 10 and the engine speed N. Namely, as shown in Fig. 3, in a low load operation region on the lower load side from a solid line R, K becomes smaller than 1.0, that is, the air-fuel ratio of the air-fuel mixture is made lean, and in a high load operation region between the solid line R and solid line S, K becomes equal to 1.0,

that is, the air-fuel ratio of the air-fuel mixture is made the stoichiometric air-fuel ratio. In the full load operation region on the higher load side from the solid line S, K becomes larger than 1.0, that is, the air-fuel ratio of the air-fuel mixture is made rich.

[0016] Figure 4 schematically shows the concentration of representative components in the exhaust gas discharged from the combustion chamber 3. As seen from Fig. 4, the concentration of the unburnt HC and CO in the exhaust gas discharged from the combustion chamber 3 is increased as the air-fuel ratio of the air-fuel mixture supplied into the combustion chamber 3 becomes rich, and the concentration of the oxygen O_2 discharged from the combustion chamber 3 is increased as the air-fuel ratio of the air-fuel mixture supplied into the combustion chamber 3 becomes lean.

[0017] A NO_x absorbent 18 accommodated in the casing 17 uses for example alumina as the carrier. On this carrier, at least one element selected from alkali metals such as for example potassium K, sodium Na, lithium Li, and cesium Cs, alkali earth metals such as barium Ba or calcium Ca, and rare earth metals such as lanthanum La or yttrium Y and a precious metal such as platinum Pt are carried. When the ratio of the air and fuel (hydrocarbon) supplied into the engine intake passage and the exhaust passage upstream of the NO_x absorbent 18 is referred to as the air-fuel ratio of the inflowing exhaust gas into the NO_x absorbent 18, this NO_x absorbent 18 performs the action of absorbing and releasing NO_x so as to absorb the NO_x when the air-fuel ratio of the inflowing exhaust gas is lean and release the absorbed NO_x when the oxygen concentration in the inflowing exhaust gas is lowered. Note that, where the fuel (hydrocarbon) or the air is not supplied into the exhaust passage upstream of the NO_x absorbent 18, the air-fuel ratio of the flowing exhaust gas coincides with the air-fuel ratio of the air-fuel mixture supplied into the combustion chamber 3, and therefore, in this case, the NO_x absorbent 18 absorbs the NO_x when the air-fuel ratio of the air-fuel mixture supplied into the combustion chamber 3 is lean and releases the absorbed NO_x when the oxygen concentration in the air-fuel mixture supplied into the combustion chamber 3 is lowered.

[0018] When the NO_x absorbent 18 is arranged in the engine exhaust passage, this NO_x absorbent 18 actually performs the absorbing and releasing action of NO_x, but there are areas of uncertainty regarding the detailed mechanism of this absorbing and releasing action. However, it can be considered that this absorbing and releasing action is carried out by the mechanism as shown in Figs. 5A and 5B. Next, an explanation will be made of this mechanism by taking as an example a case where platinum Pt and barium Ba are carried on this carrier, but a similar mechanism is obtained even if an other precious metal or alkali metal, alkali earth metal, and rare earth metal are used.

[0019] Namely, when the inflowing exhaust gas becomes considerably lean, the oxygen concentration in the inflowing exhaust gas is greatly increased, and as shown in Fig. 5A, the oxygen O_2 is deposited on the surface of the platinum Pt in the form of O_2^- or O^{2-}. On the other hand, the NO in the inflowing exhaust gas reacts with O_2^- or O^{2-} on the surface of the platinum Pt and becomes NO_2 ($2NO + O_2 \rightarrow 2NO_2$). Subsequently, one part of the generated NO_2 is absorbed into the absorbent while being oxidized on the platinum Pt and bonded to the barium oxide BaO while being diffused in the absorbent in the form of a nitric acid ion NO_3^- as shown in Fig. 5A. In this way, NO_x is absorbed into the NO_x absorbent 18.

[0020] So far as the oxygen concentration in the inflowing exhaust gas is high, NO_2 is generated on the surface of the platinum Pt, and so far as the NO_x absorbing capability of the absorbent is not saturated, the nitric acid ion NO_3^- formed by absorption of NO_2 into the absorbent is generated. Contrary to this, when the oxygen concentration in the flowing exhaust gas is lowered and the amount of generation of the NO_2 is lowered, the reaction advances in a reverse direction ($NO_3^- \rightarrow NO_2$), and thus the nitric acid ion NO_3^- in the absorbent is released from the absorbent in the form of NO_2. Namely, when the oxygen concentration in the flowing exhaust gas is lowered, NO_x will be released from the NO_x absorbent 18. As shown in Fig. 4, when the degree of leanness of the inflowing exhaust gas becomes low, the oxygen concentration in the inflowing exhaust gas is lowered, and therefore when the degree of the leanness of the inflowing exhaust gas is lowered, even if the air-fuel ratio of the inflowing exhaust gas is lean, NO_x will be released from the NO_x absorbent 18.

[0021] On the other hand, when the air-fuel ratio of the air-fuel mixture supplied into the combustion chamber 3 is made rich and the air-fuel ratio of the inflowing exhaust gas becomes rich, as shown in Fig. 4, a large amount of unburnt HC and CO are discharged from the engine. These unburnt HC and CO react with the oxygen O_2^- or O^{2-} on the platinum Pt and are oxidized. Further, when the air-fuel ratio of the inflowing exhaust gas becomes rich, the oxygen concentration in the inflowing exhaust gas is extremely lowered, so NO_2 is released from the absorbent. This NO_2 reacts with the unburnt HC and CO and is reduced as shown in Fig. 5B. In this way, when NO_2 no longer exists on the surface of the platinum Pt, the NO_2 is successively released from the absorbent. Accordingly, when the air-fuel ratio of the inflowing exhaust gas is made rich, the NO_x will be released from the NO_x absorbent 18 in a short time.

[0022] Namely, when the air-fuel ratio of the inflowing exhaust gas is made rich, first of all, the unburnt HC and CO immediately react with O_2^- or O^{2-} on the platinum Pt and are oxidized, and then even if the O_2^- or O^{2-} on the platinum Pt is consumed, if the unburnt HC and CO still remain, the NO_x released from the absorbent and the NO_x discharged from the engine are reduced. Accordingly, if the air-fuel ratio of the inflowing exhaust gas is made rich, the NO_x absorbed in the NO_x absorbent 18

is released in a short time, and, in addition, this released NO_x is reduced, so it becomes possible to prevent the NO_x from being discharged into the atmosphere.

[0023] As mentioned above, when the lean air-fuel mixture is burned, NO_x is absorbed into the NO_x absorbent 18. However, there is a limit to the NO_x absorbing ability of the NO_x absorbent 18. When the NO_x absorbing capability of the NO_x absorbent 18 is saturated, the NO_x absorbent 18 no longer can absorb the NO_x. Accordingly, it is necessary to release the NO_x from the NO_x absorbent 18 before the NO_x absorbing capability of the NO_x absorbent 18 is saturated. For this purpose, it is necessary to estimate to what degree the NO_x has been absorbed in the NO_x absorbent 18. Next, an explanation will be made of the estimation method of this amount of absorption of NO_x.

[0024] When the lean air-fuel mixture is burned, the higher the engine load, the larger the amount of NO_x discharged from the engine per unit time, so the amount of NO_x absorbed into the NO_x absorbent 18 per unit time is increased. Also, the higher the engine speed, the larger the amount of NO_x discharged from the engine per unit time, so the amount of NO_x absorbed into the NO_x absorbent 18 per unit time is increased. Accordingly, the amount of NO_x absorbed into the NO_x absorbent 18 per unit time becomes a function of the engine load and the engine speed. In this case, the engine load can be represented by the absolute pressure in the surge tank 10, so the amount of NO_x absorbed into the NO_x absorbent 18 per unit time becomes a function of the absolute pressure PM in the surge tank 10 and the engine speed N. Accordingly, in the embodiment according to the present invention, the amount of NO_x absorbed into the NO_x absorbent 18 per unit time is found in advance as a function of the absolute pressure PM and the engine speed N by experiments. These amounts of absorption of NO_x NOXA and PM are stored in advance in the ROM 32 in the form of a map shown in Fig. 6 as a function of PM and N.

[0025] On the other hand, as mentioned before, during the period where the NO_x is released from the NO_x absorbent 18, the unburnt HC and CO contained in the exhaust gas, that is, the excess fuel, is used for reducing the NO_x released from the NO_x absorbent 18, therefore the amount NOXD of NO_x released from the NO_x absorbent 18 per unit time becomes proportional to the amount of excess fuel supplied per unit time. Note that the amount Q_{ex} of excess fuel supplied per unit time can be represented by the following equation:

$$Q_{ex} = f_1 \circ (K - 1.0) \circ TP \circ N$$

[0026] Here, f_1 indicates a proportional constant, K, a correction coefficient, TP a basic fuel injection time, and N, an engine speed. On the other hand, when the proportional constant is f_2, the amount NOXD of NO_x released from the NO_x absorbent 18 per unit time can be represented by

$$NOXD = f_2 \circ Q_{ex}$$

so if $f = f_1 \circ f_2$, the amount NOXD of NO_x released from the NO_x absorbent 18 per unit time can be represented by the following equation:

$$NOXD = f \circ (K - 1.0) \circ TP \circ N$$

[0027] As mentioned above, when a lean air-fuel mixture is burned, the amount of absorption of NO_x per unit time is represented by NOXD, and when a rich air-fuel mixture is burned, the amount of release of NO_x per unit time is represented by NOXD, therefore the amount ΣNOX of NO_x estimated to be absorbed in the NO_x absorbent 18 will be represented by the following equation:

$$\Sigma NOX = \Sigma NOX + NOXA - NOXD$$

[0028] Therefore, in the embodiment according to the present invention, as shown in Fig. 7, when the amount ΣNOX of the NO_x estimated to be absorbed in the NO_x absorbent 18, in practice, the corrected amount of estimation of NO_x ΣNKX mentioned later, reaches the allowable maximum value MAX, the air-fuel ratio of the air-fuel mixture is temporarily made rich, whereby NO_x is released from the NO_x absorbent 18.

[0029] However, SO_x is contained in the exhaust gas, and not only NO_x, but also SO_x are absorbed into the NO_x absorbent 18. The absorbing mechanism of SO_x to the NO_x absorbent 18 can be considered to be the same as the absorption mechanism of NO_x.

[0030] Namely, similar to the explanation of the absorbing mechanism of NO_x, when the explanation is made by taking as an example a case where platinum Pt and barium Ba are carried on the carrier, as mentioned before, when the air-fuel ratio of the inflowing exhaust gas is lean, the oxygen O_2 is deposited on the surface of the platinum Pt in the form of O_2^- or O^{2-}, and the SO_2 in the inflowing exhaust gas reacts with the O_2^- or O^{2-} on the surface of the platinum Pt and becomes SO_3. Subsequently, one part of the generated SO_3 is absorbed into the absorbent while being further oxidized on the platinum Pt and bonded to the barium oxide BaO while being diffused in the absorbent in the form of a sulfuric acid ion SO_4^{2-} and stable sulfate $BaSO_4$ is generated.

[0031] However, this sulfate $BaSO_4$ is stable and hard to decompose. Even if the air-fuel ratio of the air-fuel mixture is made rich for just a short time as shown in Fig. 7, most of the sulfate $BaSO_4$ is not decomposed and remains as it is. Accordingly, the sulfate $BaSO_4$ is increased in the NO_x absorbent 18 along with the elapse of time, and thus the maximum amount of absorption of

NO_x which can be absorbed by the NO_x absorbent 18 will be gradually lowered along with the elapse of time. Namely, in other words, the NO_x absorbent 18 will gradually deteriorate along with the elapse of time. When the maximum amount of absorption of NO_x by the NO_x absorbent 18 is lowered, it is necessary to release the NO_x from the NO_x absorbent 18 in a period when the amount of absorption of the NO_x in the NO_x absorbent 18 is small. For this purpose, first, it becomes necessary to correctly detect the maximum amount of absorption of NO_x possible by the NO_x absorbent 18, that is, the degree of deterioration of the NO_x absorbent 18.

[0032] In the embodiment according to the present invention, the maximum amount of absorption of NO_x possible by the NO_x absorbent 18, that is, the degree of deterioration of the NO_x absorbent 18, is detected from the air-fuel ratio detected by the O_2 sensor 22. This will be explained later.

[0033] Namely, when the air-fuel ratio of the air-fuel mixture supplied into the combustion chamber 3 becomes rich, as shown in Fig. 4, the exhaust gas containing the oxygen O_2 and the unburnt HC and CO is discharged from the combustion chamber 3, but this oxygen O_2 and the unburnt HC and CO do not react much at all with each other, and thus this oxygen O_2 passes through the NO_x absorbent 18 and is discharged from the NO_x absorbent 18. On the other hand, when the air-fuel ratio of the air-fuel mixture supplied into the combustion chamber 3 becomes rich, NO_x is released from the NO_x absorbent 18. At this time, the unburnt HC and CO contained in the exhaust gas is used for reducing the released NO_x, so during a period when the NO_x is released from the NO_x absorbent 18, no unburnt HC and CO are discharged from the NO_x absorbent 18. Accordingly, during a period when the NO_x is continuously released from the NO_x absorbent 18, the oxygen O_2 is contained in the exhaust gas discharged from the NO_x absorbent 18, but no unburnt HC and CO are contained, therefore during this term, the air-fuel ratio of the exhaust gas discharged from the NO_x absorbent 18 becomes slightly lean.

[0034] Subsequently, when all of the NO_x absorbed in the NO_x absorbent 18 is released, the unburnt HC and CO contained in the exhaust gas are not used for the reduction of the O_2 in the NO_x absorbent 18 but are discharged as they are from the NO_x absorbent 18. Accordingly, the air-fuel ratio of the exhaust gas discharged from the NO_x absorbent 18 becomes rich at this time. Namely, when all of the NO_x absorbed in the NO_x absorbent 18 is released, the air-fuel ratio of the exhaust gas discharged from the NO_x absorbent 18 changes from lean to rich. Accordingly, all of the NO_x absorbed in the NO_x absorbent 18 is released from the NO_x absorbent 18 during the time elapsing from when the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent 18 is changed from lean to rich to when the air-fuel ratio of the exhaust gas discharged from the NO_x absorbent 18 becomes rich. Therefore, from this, the amount of NO_x absorbed in the NO_x absorbent 18 is seen. This will be explained in slightly detail more next.

[0035] The O_2 sensor 22 shown in Fig. 1 comprises a cup-like cylindrical body made of zirconia arranged in the exhaust passage. An anode made of a thin platinum film is formed on an inside surface of this cylindrical body and a cathode made of a thin platinum film is formed on an outside surface of this cylindrical body, respectively. The cathode is covered by a porous layer. Constant voltage is applied between the cathode and anode. In this O_2 sensor 22, as shown in Fig. 9, a current I (mA) proportional to the air-fuel ratio A/F flows between the cathode and anode. Note that, in Fig. 9, I_0 indicates the current when the air-fuel ratio A/F is the stoichiometric air-fuel ratio (= 14.6). As seen from Fig. 9, when the air-fuel ratio A/F is lean, the current I is increased as the air-fuel ratio A/F becomes larger within a range where $I > I_0$, and the current I becomes zero when the air-fuel ratio A/F becomes rich of almost 13.0 or less.

[0036] Figure 10 shows the change of the air-fuel ratio $(A/F)_{in}$ of the exhaust gas flowing into the NO_x absorbent 18, the change of the current I flowing between the cathode and anode of the O_2 sensor 22, and the change of the air-fuel ratio (A/F) of the exhaust gas flowing out from the NO_x absorbent 18. As shown in Fig. 10, when the air-fuel ratio (A/F) of the exhaust gas flowing into the NO_x absorbent 18 is changed from lean to rich and the NO_x releasing action from the NO_x absorbent 18 is started, the air-fuel ratio $(A/F)_{out}$ of the exhaust gas flowing out from the NO_x absorbent 18 abruptly becomes small to near the stoichiometric air-fuel ratio, and therefore the current I is abruptly decreased to near I_0. Subsequently, in a term when the NO_x releasing action from the NO_x absorbent 18 is carried out, the air-fuel ratio $(A/F)_{out}$ of the exhaust gas flowing out from the NO_x absorbent 18 is held in a slightly lean state, and therefore the current I is held at a value slightly larger than the I_0. Subsequently, when all of the NO_x absorbed in the NO_x absorbent 18 is released, the air-fuel ratio (A/F) of the exhaust gas flowing out from the NO_x absorbent 18 abruptly becomes small and becomes rich, and therefore the current I abruptly falls to zero.

[0037] Figure 11 shows the change of the current I where the amount of NO_x contained in the NO_x absorbent 18 differs. Note that, in Fig. 11, the numerical values indicate the amount of NO_x absorbed in the NO_x absorbent 18. As shown in Fig. 11, when the amount of NO_x absorbed in the NO_x absorbent 18 is different, along with this, an elapsed time t from when the air-fuel ratio $(A/F)_{in}$ of the exhaust gas flowing into the NO_x absorbent 18 is changed from lean to rich to when the current I becomes almost zero changes. The smaller the amount of NO_x absorbed in the NO_x absorbent 18, the shorter this elapsed time. NO_x is continuously released from the NO_x absorbent 18 for almost this elapsed time t. If the entire amount of NO_x released during this elapsed time t is found, the entire amount of NO_x absorbed in the NO_x absorbent 18 will be seen.

[0038] Note that, as mentioned before, the amount of release of NOXD NO_x released from the NO_x absorbent 18 is represented by the following equation:

$$NOXD = f_1 \circ (K - 1.0) \circ TP \circ N$$

[0039] Accordingly, if the total sum of the amount of release of NO_x NOXD during the elapsed time t is found, the entire amount of NO_x actually absorbed in the NO_x absorbent 18 can be detected.

[0040] By the say, to detect the maximum amount of absorption of NO_x possible by the NO_x absorbent 18, that is, the degree of deterioration of the NO_x absorbent 18, at detection, the amount of absorption ΣNOX of NO_x of the NO_x absorbent 18 must become the maximum amount of absorption of NO_x. Namely, when assuming that the VNO_x indicated by the broken line in Fig. 7 is the maximum amount of absorption of NO_x which is actually possible, when the amount of absorption of NO_x ΣNOX of the NO_x absorbent 18 is smaller than this VNO_x, even if all of the NO_x is released from the NO_x absorbent 18, the maximum amount of absorption of NO_x VNO_x cannot be found. This is because the entire amount of NO_x released at this time is smaller than the maximum amount of absorption of NO_x.

[0041] Contrary to this, when the NO_x is released from the NO_x absorbent 18 when the absorbing capability of the NO_x absorbent 18 is saturated, the entire amount of NO_x released at this time represents the maximum amount of absorption of NO_x VNO_x. Therefore, in the embodiment according to the present invention, a decision level SAT which is slightly larger than the value near the maximum amount of absorption of NO_x VNO_x at present is set, and as shown in Fig. 7. When the amount of absorption of NO_x ΣNOX of the NO_x absorbent 18 reaches this decision level SAT, the entire NO_x is released from the NO_x absorbent 18, whereby the actual amount of absorption of NO_x VNO_x, that is, the degree of deterioration of the NO_x absorbent 18 at this time, is found.

[0042] Note that, as shown in Fig. 7, the allowable maximum value MAX with respect to the amount of NO_x ΣNOX is set to a value smaller than the maximum amount of absorption of NO_x VNO_x, and when the ΣNOX reaches the allowable maximum value MAX, the decision of deterioration of the NO_x absorbent 18 is not carried out, and only the action of releasing NO_x from the NO_x absorbent 18 is carried out. The frequency of only the action of releasting the NO_x from the NO_x absorbent 18 being carried out is higher than the frequency of the decision of deterioration of the NO_x absorbent 18 being carried out, and therefore for a period after the decision of deterioration of the NO_x absorbent 18 is carried out and until the next decision of deterioration of the NO_x absorbent 18 is carried out, a number of actions of releasing NO_x are carried out.

[0043] The amount of absorption of NO_x ΣNOX of the NO_x absorbent 18 is, however, an estimated amount as mentioned before, and therefore this amount of absorption of NO_x ΣNOX does not always represent the actual amount of absorption of NO_x. In this case, if for example the amount of absorption of NO_x ΣNOX indicates a considerably higher value than the actual amount of absorption of NO_x, even if the amount of absorption of NO_x ΣNOX reaches the decision level SAT, the actual amount of absorption of NO_x does not reach the actual maximum amount of absorption of NO_x VNO_x, and thus there arises a problem in that the actual maximum amount of absorption of NO_x VNO_x cannot be correctly detected.

[0044] Therefore, in the embodiment according to the present invention, a correction value KX with respect to the amount of absorption of NO_x ΣNOX is introduced. Whenever the amount of absorption of NO_x ΣNOX reaches the allowable maximum value MAX and the release of NO_x from the NO_x absorbent 18 is carried out, the actual amount of absorption of NO_x XNO_x is calculated on the basis of the output signal of the NO_x sensor 22, and the correction value KX is updated on the basis of the following equation:

$$KX = KX \circ (XNO_x/\Sigma NOX)$$

[0045] In this case, the corrected estimated amount of NO_x is represented by ΣNKX (= KX ∘ ΣNOX). Namely, where for example the estimated amount of absorption of NO_x ΣNOX becomes smaller than the actual amount of absorption of NO_x XNO_x, the value of the correction value KX is increased with respect to the value of the correction value KX which has been used heretofore so that ΣNKX (= KX ∘ ΣNOX) coincides with XNO_x. Accordingly, in the embodiment according to the present invention, in actuality, not when the estimated amount of NO_x ΣNOX reaches MAX, but when the corrected estimated amount of NO_x ΣNOX reaches the allowable maximum value MAX, the action of releasing NO_x is carried out.

[0046] When the maximum amount of absorption of NO_x VNO_x becomes small, that is, when the degree of deterioration of the NO_x absorbent 18 becomes high, the allowable maximum value MAX becomes small, and thus as seen from Fig. 7, a cycle at which the air-fuel ratio is made rich for releasing NO_x becomes short. Further, when the degree of deterioration of the NO_x absorbent 18 becomes high and the allowable maximum value MAX becomes small, the time required for the release of NO_x becomes short, so the time during which the air-fuel ratio is maintained rich becomes short. Accordingly, when the degree of deterioration of the NO_x absorbent 18 is low, as shown in Fig. 8A, a cycle t_1 when the air-fuel ratio is made rich and the time t_2 during which the air-fuel ratio is maintained rich are relatively long, and when the degree of deterioration of the NO_x absorbent 18 becomes high, as shown in Fig. 8B, a cycle when the air-fuel ratio is made rich and the time during which

the air-fuel ratio is maintained rich become short.

[0047] As mentioned above, in the embodiment according to the present invention, the actual amount of NO_x VNO_x and XNO_x are calculated on the basis of the current I flowing between the cathode and anode of the O_2 sensor 22 and the air-fuel ratio is controlled for releasing NO_x on the basis of these values VNO_x and XNO_x. In this case, the current I flowing between the cathode and anode of the O_2 sensor 22 is converted to a voltage and input into the input port 36. In the electronic control unit 30, this voltage is converted to the corresponding current I again and the air-fuel ratio is controlled on the basis of the current value I.

[0048] Figure 12 and Fig. 13 show a routine for control of the air-fuel ratio. This routine is executed by interruption at every predetermined time interval.

[0049] Referring to Fig. 12 and Fig. 13, first of all, at step 100, a basic fuel injection time TP is calculated from the relationship shown in Fig. 2. Subsequently, at step 101, it is determined whether or not a decision of deterioration flag indicating that the degree of deterioration of the NO_x absorbent 18 should be decided has been set. When the decision of deterioration flag has not been set, the processing routine proceeds to step 102, where it is determined whether or not the NO_x releasing flag indicating that the NO_x should be released from the NO_x absorbent 18 has been set. When the NO_x releasing flag has not been set, the processing routine proceeds to step 103.

[0050] At step 103, the correction coefficient K is calculated on the basis of Fig. 3. Subsequently, at step 104, it is determined whether or not the correction coefficient K is 1.0. When K = 1.0, that is, when the air-fuel ratio of the air-fuel mixture should be made the stoichiometric air-fuel ratio, the processing routine proceeds to step 126, at which the feedback control I of the air-fuel ratio is carried out. This feedback control I is shown in Fig. 14. On the other hand, when K does not equal 1.0, the processing routine proceeds to step 105, at which it is determined whether or not the correction coefficient K is smaller than 1.0. When K < 1.0, that is, when the air-fuel ratio of the lean air-fuel mixture should be made lean, the processing routine proceeds to step 127, at which the feedback control II of the air-fuel ratio is carried out. This feedback control II is shown in Fig. 16. On the other hand, when K is not smaller than 1.0, the processing routine proceeds to step 106, at which FAF is fixed to 1.0, and then the processing routine proceeds to step 107. At step 107, the fuel injection time TAU is calculated on the basis of the following equation:

$$TAU = TP \bullet K \bullet FAF$$

[0051] Subsequently, at step 108, it is determined whether or not the correction coefficient K is smaller than 1.0. When K < 1.0, that is, when a lean air-fuel mixture should be burned, the processing routine proceeds to step 109, at which the amount of absorption of NO_x NOXA is calculated from Fig. 6. Subsequently, at step 110, the amount of absorption of NO_x NOXD is made zero, and then the processing routine proceeds to step 113. Contrary to this, at step 108, when $K \leq 1.0$ is determined, that is, when an air-fuel mixture of the stoichiometric air-fuel ratio or the rich air-fuel mixture should be burned, the processing routine proceeds to step 111, at which the amount of absorption of NO_x NOXD is calculated on the basis of the following equation:

$$NOXD = f \bullet (K - 1) \bullet TP \bullet N$$

[0052] Subsequently, at step 112, the amount of absorption of NO_x NOXA is made zero, and then the processing routine proceeds to step 113. At step 113, the amount ΣNOX estimated to be absorbed in the NO_x absorbent 18 is calculated on the basis of the following equation.

$$\Sigma NOX = \Sigma NOX + NOXA - NOXD$$

[0053] Subsequently, at step 114, by multiplying the estimated amount of NO_x ΣNOX by KX, the corrected estimated amount of NO_x, that is, the actual amount of NO_x ΣNKX is calculated. Subsequently, at step 115, it is determined whether or not the ΣNOX becomes negative. When ΣNOX becomes smaller than 0, the processing routine proceeds to step 116, at which the ΣNOX is made zero. Subsequently, at step 117, a current vehicle speed SP is added to ΣSP. This ΣSP indicates the cumulative traveling distance of the vehicle. Subsequently, at step 118, it is determined whether or not the cumulative travelling distance ΣSP is larger than the set value SP_0. When $ESP \leq SP_0$, the processing routine proceeds to step 119, at which it is determined whether or not the ΣNKX exceeds the allowable maximum value MAX (Fig. 7). When ΣNKX becomes larger than MAX, the processing routine proceeds to step 120, at which the NO_x releasing flag is set.

[0054] On the other hand, when it is determined at at step 118 that $\Sigma SP > SP_0$, the processing routine proceeds to step 121, at which it is determined whether or not the amount of NO_x ΣNKX becomes larger than SAT (Fig. 7). When ΣNKX becomes larger than SAT, the processing routine proceeds to step 122, at which the decision of deterioration flag is set, and then at step 123, ΣSP is made zero.

[0055] When the decision of deterioration flag is set, the processing routine goes from step 101 to step 124, at which the decision of deterioration is carried out. This decision of deterioration is shown in Fig. 18. On the other hand, when the NO_x releasing flag is set, the processing routine proceeds from step 102 to step 125, at which the processing for release of NO_x is performed. This processing for release of NO_x is shown in Fig. 17.

[0056] Next, an explanation will be made of the feedback control I to be carried out at step 126 of Fig. 12, that is, the feedback control for maintaining the air-fuel ratio at the stoichiometric air-fuel ratio on the basis of the output signal of the O_2 sensor 22 referring to Fig. 14 and Fig. 15.

[0057] As shown in Fig. 15, the O_2 sensor 20 generates an output voltage V of about 0.9V when the air-fuel ratio of the air-fuel mixture is rich and generates an output voltage V of about 0.1 V when the air-fuel ratio of the air-fuel mixture is lean. The feedback control I shown in Fig. 14 is carried out on the basis of the output signal of this O_2 sensor 20.

[0058] Referring to Fig. 14, first of all, it is determined at step 130 whether or not the output voltage V of the O_2 sensor 20 is smaller than a reference voltage Vr of about 0.45V. When $V \leq Vr$, that is, when the air-fuel ratio is lean, the processing routine proceeds to step 131, at which the delay count CDL is decremented exactly by one. Subsequently, at step 132, it is determined whether or not the delay count CDL becomes smaller than the minimum value TDR. When CDL becomes smaller than TDR, the processing routine proceeds to step 133, at which the CLD is made TDR and then the processing routine proceeds to step 137. Accordingly, as shown in Fig. 15, when V becomes equal to or smaller than Vr, the delay count value CDL is gradually decreased, and subsequently, the CDL is maintained at the minimum value TDR.

[0059] On the other hand, when it is determined at step 130 that $V > Vr$, that is, when the air-fuel ratio is rich, the processing routine proceeds to step 134, at which the delay count CDL is incremented exactly by one. Subsequently, at step 135, it is determined whether or not the delay count CDL becomes larger than the maximum value TDL. When CDL becomes larger than TDL, the processing routine proceeds to step 136, at which the CDL is made TDL and then the processing routine proceeds to step 137. Accordingly, as shown in Fig. 15, when V becomes larger than Vr, the delay count CDL is gradually increased, and then CDL is maintained at the maximum value TDL.

[0060] At step 137, it is determined whether or not the sign of the delay count CDL is inverted from positive to negative or from negative to positive in a period from the previous processing cycle to this processing cycle. When the sign of the delay count CDL is inverted, the processing routine proceeds to step 138, at which it is determined whether or not it is an inversion from positive to negative, that is, whether or not it is an inversion from rich to lean. When it is an inversion from rich to lean, the processing routine proceeds to step 139, at which the rich skip value RSR is added to the feedback correction coefficient FAF and thus, as shown in Fig. 15, the FAF is abruptly increased exactly by the rich skip value RSR. Contrary to this, at the time of an inversion from lean to rich, the processing routine proceeds to step 140, at which the lean skip value RSL is subtracted from the FAF, and thus as shown in Fig. 15, the FAF is abruptly decreased exactly by the lean skip value RSL.

[0061] On the other hand, when it is determined at step 137 that the sign of the delay count CDL is not inverted, the processing routine proceeds to step 141, at which it is determined whether or not the delay count CDL is negative. When $CDL \leq 0$, the processing routine proceeds to step 142, at which the rich integration value KIR ($KIR < RSR$) is added to the feedback correction coefficient FAF, and thus as shown in Fig. 15, the FAF is gradually increased. On the other hand, when $CDL > 0$, the processing routine proceeds to step 143, at which rich integration value KIL ($KIL < RSL$) is subtracted from FAF, and thus the FAF is gradually decreased as shown in Fig. 15. In this way, the air-fuel ratio is controlled to the stoichiometric air-fuel ratio.

[0062] Next, an explanation will be made of the feedback control for maintaining the air-fuel ratio to the target lean air-fuel ratio corresponding to the correction coefficient K on the basis of the feedback control II carried out at step 127 of Fig. 12, that is, the current I of the O_2 sensor 22, referring to Fig. 16.

[0063] Referring to Fig. 16, first of all, at step 150, the target current value I_0 corresponding to the target lean air-fuel ratio is calculated from the relationship shown in Fig. 9. Subsequently, at step 151, it is determined whether or not the current I of the O_2 sensor 22 is larger than the target current I_0. When $I > I_0$, the processing routine proceeds to step 152, at which a constant value ΔF is added to the feedback correction coefficient FAF, and when $I \leq I_0$, the processing routine proceeds to step 153, at which the constant value ΔF is subtracted from the feedback correction coefficient FAF. In this way, the air-fuel ratio is maintained at the target lean air-fuel ratio.

[0064] Next, an explanation will be made of the control for release of NO_x carried out at step 125 of Fig. 12 referring to Fig. 17.

[0065] Referring to Fig. 17, first of all, at step 160, the correction coefficient K is made a constant value KK of for example about 1.3. Subsequently, at step 161, the fuel injection time TAU is calculated on the basis of the following equation:

$$TAU = TP \circ K$$

[0066] Accordingly, when the processing for release of NO_x is started, the feedback control of the air-fuel ratio is stopped, and the air-fuel ratio of the air-fuel mixture is made rich. Subsequently, at step 162, the amount of release NOXD of the NO_x released from the NO_x absorbent 18 per unit time is calculated as follows:

$$NOXD = f \circ (K - 1.0) \circ TP \circ N$$

[0067] Subsequently, at step 163, the amount of release XNO_x of NO_x actually released from the NO_x ab-

sorbent 18 is calculated on the basis of the following equation. Note that, in the following equation, Δt represents the interval of the time interruption.

$$XNO_x = XNO_x + NOXD \bullet \Delta t$$

[0068] Subsequently, at step 164, it is determined whether or not the current I of the O_2 sensor 22 becomes lower than the predetermined constant value α (Fig. 11). When I becomes smaller than α, the processing routine proceeds to step 165, at which it is determined whether or not the absolute value $|XNO_x - \Sigma NKX|$ of the difference between the actual amount of release of NO_x XNO_x and the corrected estimated amount of absorption of NO_x ΣNKX is larger than the constant value β. When $|XNO_x - \Sigma NKX| \leq \beta$, the processing routine jumps to step 167. Contrary to this, when $|XNO_x - \Sigma NKX| > \beta$, the processing routine proceeds to step 166, at which the correction value KX is corrected on the basis of the following equation:

$$KX = KX \bullet XNO_x / \Sigma NKX$$

[0069] Subsequently, at step 167, the NO_x releasing flag is reset, and thus the air-fuel ratio of the air-fuel mixture is changed to the air-fuel ratio determined according to the operating state at that time, usually lean. Subsequently, at step 168, XNO_x and ΣNOX are made zero.

[0070] Next, an explanation will be made of the decision of deterioration carried out at step 124 of Fig. 12 referring to Fig. 18.

[0071] Referring to Fig. 18, first of all, at step 170, the correction coefficient K is made the constant value KK of for example about 1.3. Subsequently, at step 171, the fuel injection time TAU is calculated on the basis of the following equation:

$$TAU = TP \bullet K$$

[0072] Accordingly, when the decision of deterioration is started, the feedback control of the air-fuel ratio is stopped, and the air-fuel ratio of the air-fuel mixture is made rich. Subsequently, at step 172, the amount of release NOXD of NO_x released from the NO_x absorbent 18 is calculated based on the following equation:

$$NOXD = f \bullet (K - 1.0) \bullet TP \bullet N$$

[0073] Subsequently, at step 173, the amount of release VNO_x of NO_x actually released from the NO_x absorbent 18 is calculated on the basis of the following equation. Note that, in the following equation, Δt represents the interval of the time interruption.

$$VNO_x = VNO_x + NOXD \bullet \Delta t$$

[0074] Subsequently, at step 174, it is determined whether or not the current I of the O_2 sensor 22 becomes lower than the predetermined constant value α (Fig. 11). When I becomes smaller than α, the processing routine proceeds to step 175, at which by multiplying the VNO_x by a constant value larger than 1.0, for example 1.1, the decision level SAT (= 1.1 • VNO_x) is calculated. In this way, the decision level SAT is set to a value larger than VNO_x, so this VNO_x represents the maximum amount of absorption of NO_x possible by the NO_x absorbent 18. Namely, if VNO_x represents an amount of absorption of NO_x smaller than the maximum amount of absorption of NO_x, the decision level SAT becomes large whenever the decision of deterioration is carried out, and thus finally the VNO_x represents the maximum amount of absorption of NO_x, that is, the degree of deterioration of the NO_x absorbent 18.

[0075] So as to find the decision level SAT, of course it is also possible to multiply another numerical value other than 1.1 with VNO_x, and the decision level SAT can be found by multiplying any number of 1.0 or more with VNO_x. Note, if the numerical value to be multiplied with VNO_x is made too large, the time from when the amount of absorption of NO_x of the NO_x absorbent 18 becomes the maximum amount of absorption of NO_x to when the action of release of NO_x is carried out becomes too long, so the amount of NO_x discharged to the atmosphere is increased. Accordingly, it is not preferred that the numerical value to be multiplied with VNO_x be set too large. This numerical value is preferably about 1.3 or less.

[0076] When the decision level SAT is calculated at step 175, the processing routine proceeds to step 176, at which by multiplying a positive numerical value of 1.0 or less, for example 0.8, with the VNO_x, the allowable maximum value MAX (= 0.8 • VNO_x) is calculated. Namely, the allowable maximum value MAX is also updated in accordance with the degree of deterioration of NO_x absorbent 18. Subsequently, at step 177, it is determined whether or not the maximum amount of absorption of NO_x VNO_x reaches the predetermined minimum value MIN. When VNO_x becomes smaller than MIN, the processing routine proceeds to step 178, at which the alarm lamp 25 is turned on. Subsequently, at step 179, the decision of deterioration flag is reset. When the decision of deterioration flag is reset, the air-fuel ratio of the air-fuel mixture is changed to the air-fuel ratio in accordance with the operating state at that time, usually lean. Subsequently, at step 180, VNO_x and ΣNOX are made zero.

[0077] Figure 19 to Fig. 23 show another embodiment. Also in this embodiment, the decision of deterioration of the NO_x absorbent 18 is carried out when the corrected amount of absorption of NO_x ΣNKX exceeds the decision level SAT, but control for release of NO_x

from the decision of deterioration to when the next decision of deterioration is carried out can be carried out by a simpler method compared with the first embodiment. Namely, in this embodiment, as shown in Figs. 19A and 19B, a cycle TL at which the air-fuel ratio of the air-fuel mixture is made rich so as to release the NO_x from the NO_x absorbent 18 and the rich time TR of the air-fuel mixture at this time are determined in accordance with the maximum amount of absorption of NO_x VNO_x, that is, the degree of deterioration of the NO_x absorbent 18. Namely, as shown in Fig. 19A, the lower the maximum amount of absorption of NO_x VNO_x, in other words, the larger the degree of deterioration of the NO_x absorbent 18, the shorter the cycle TL at which the air-fuel ratio of the air-fuel mixture is made rich, and as shown in Fig. Fig. 19B, the lower the maximum amount of absorption of NO_x VNO_x, in other words, the larger the degree of deterioration of the NO_x absorbent 18, the shorter the rich time TR of the air-fuel mixture. Note that, the relationships shown in Figs. 19A and 19B are preliminarily stored in the ROM 32.

[0078] Figure 20 and Fig. 21 show the routine for control of the air-fuel ratio for this second embodiment. This routine is executed by interruption at every predetermined time interval.

[0079] Referring to Fig. 20 and Fig. 21, first of all, at step 200, the basic fuel injection time TP is calculated from the relationship shown in Fig. 2. Subsequently, at step 201, it is determined whether or not the decision of deterioration flag indicating that the degree of deterioration of the NO_x absorbent 18 should be decided has been set. When the decision of deterioration flag has not been set, the processing routine proceeds to step 202, at which it is determined whether or not the NO_x releasing flag indicating that the NO_x should be released from the NO_x absorbent 18 has been set. When the NO_x releasing flag has not been set, the processing routine proceeds to step 203.

[0080] At step 203, the correction coefficient K is calculated on the basis of Fig. 3. Subsequently, at step 204, it is determined whether or not the correction coefficient K is 1.0. When K = 1.0, that is, when the air-fuel ratio of the air-fuel mixture is made the stoichiometric air-fuel ratio, the processing routine proceeds to step 228, at which the feedback control I of the air-fuel ratio is carried out. This feedback control I is shown in Fig. 14. On the other hand, when K is not equal to 1.0, the processing routine proceeds to step 205, at which it is determined whether or not the correction coefficient K is smaller than 1.0. When K < 1.0, that is, when the air-fuel ratio of the lean air-fuel mixture should be made lean, the processing routine proceeds to step 229, at which the feedback control II of the air-fuel ratio is carried out. This feedback control II is shown in Fig. 16. On the other hand, when K is not smaller than 1.0, the processing routine proceeds to step 206, at which the FAF is fixed to 1.0, and then the processing routine proceeds to step 207. At step 207, the fuel injection time TAU is calculated on the basis of the following equation:

$$TAU = TP \circ K \circ FAF$$

[0081] Subsequently, at step 208, it is determined whether or not the correction coefficient K is smaller than 1.0. When K < 1.0, that is, when the lean air-fuel mixture should be burned, the processing routine proceeds to step 209, at which the amount of absorption of NO_x NOXA is calculated from Fig. 6. Subsequently, at step 210, the amount of release of NO_x NOXD is made zero. Subsequently, at step 211, the interval Δt of the time interruption is added to the count value TC. Accordingly, this count TC represents the elapsed time.

[0082] At step 211, when the estimated time TC is calculated, the processing routine proceeds to step 215, at which the amount ΣNOX of NO_x estimated to be absorbed in the NO_x absorbent 18 is calculated on the basis of the following equation:

$$\Sigma NOX = \Sigma NOX + NOXA - NOXD$$

[0083] On the other hand, when it is determined at step 208 that K ≥ 1.0, that is, when the air-fuel mixture of stoichiometric air-fuel ratio or the rich air-fuel mixture should be burned, the processing routine proceeds to step 212, at which the amount of release of NO_x NOXD is calculated on the basis of the following equation:

$$NOXD = f \circ (K - 1.0) \circ TP \circ N$$

[0084] Subsequently, at step 213, the amount of absorption of NO_x NOXA is made zero, and then at step 214, the elapsed time TC is made zero. Subsequently, the processing routine proceeds to step 215, at which the estimated amount of NO_x ΣNOX is calculated.

[0085] Subsequently, at step 216, by multiplying the estimated amount of NO_x ΣNOX by the correction value KX, the corrected estimated amount of NO_x, that is, the actual amount of NO_x ΣNKX is calculated. Subsequently, at step 217, it is determined whether or not the ΣNOX becomes negative. When ΣNOX becomes smaller than 0, the processing routine proceeds to step 218, at which ΣNOX is made zero. Subsequently, at step 219, the current vehicle speed SP is added to ΣSP. This ΣSP indicates the cumulative travelling distance of the vehicle. Then, at step 220, it is determined whether or not the cumulative travelling distance ΣSP is larger than the set value SP_0. When $\Sigma SP \leq SP_0$, the processing routine proceeds to step 221, at which it is determined whether or not the elapsed time TC exceeds the cycle TL shown in Fig. 19A in accordance with the maximum amount of absorption of NO_x VNO_x. When TC becomes larger than TL, the processing routine proceeds to step 222, at which the NO_x releasing flag is set.

[0086] On the other hand, when it is determined at step 220 that $\Sigma SP > SP_0$, the processing routine proceeds to step 223, at which it is determined whether or not the ΣNKX becomes larger than the decision level SAT (Fig. 7). When ΣNKX becomes larger than SAT, the processing routine proceeds to step 224, at which the decision of deterioration flag is set, and then, at step 225, ΣSP is made zero.

[0087] When the decision of deterioration flag is set, the processing routine goes from step 201 to step 226, at which the decision of deterioration is carried out. This decision of deterioration is shown in Fig. 23. On the other hand, when the NO_x releasing flag is set, the processing routine goes from step 202 to step 227, at which the processing for release of NO_x is carried out. This processing for release of NO_x is shown in Fig. 22.

[0088] Next, an explanation will be made of the control for releasing NO_x carried out at step 227 of Fig. 20 referring to Fig. 22.

[0089] Referring to Fig. 22, first of all, at step 230, the correction coefficient K is made the constant value KK of for example about 1.3. Subsequently, at step 231, the fuel injection time TAU is calculated on the basis of the following equation:

$$TAU = TP \circ K$$

[0090] Accordingly, when the processing for release of NO_x is started, the feedback control of the air-fuel ratio is stopped, and the air-fuel ratio of the air-fuel mixture is made rich. Subsequently, at step 232, the amount of release NOXD of NO_x released from the NO_x absorbent 18 per unit time is calculated on the basis of the following equation:

$$NOXD = f_1 \circ (K - 1.0) \circ TP \circ N$$

[0091] Subsequently, at step 233, the amount of release XNO_x of NO_x actually released from the NO_x absorbent 18 is calculated on the basis of the following equation. Note that, in the following equation, Δt represents the interval of the time interruption.

$$XNO_x = XNO_x + NOXD \circ \Delta t$$

[0092] Subsequently, at step 234, it is determined whether or not a rich time TR shown in Fig. 19B in accordance with the maximum amount of absorption of NO_x VNO_x elapses from when the processing for release of NO_x is started. When the rich time TR is elapsed, the processing routine proceeds to step 235, at which it is determined whether or not absolute value $|XNO_x - \Sigma NKX|$ of the difference between the actual amount of release of NO_x XNO_x and the corrected estimated amount of absorption of NO_x ΣNKX is larger than the constant value β. When $|XNO_x - \Sigma NKX| \leq \beta$, the processing routine jumps to step 237. Contrary to this, when $|XNO_x - \Sigma NKX| > \beta$, the processing routine proceeds to step 236, at which the correction value KX is corrected based on the following equation:

$$KX = KX \circ XNO_x / \Sigma NKX$$

[0093] Subsequently, at step 237, the NO_x releasing flag is reset, and thus the air-fuel ratio of the air-fuel mixture is changed from rich to the air-fuel ratio determined according to the operating state at that time, usually lean. Subsequently, at step 238, TC, XNO_x, and ΣNOX are made zero.

[0094] Next, an explanation will be made of the decision of deterioration carried out at step 226 of Fig. 20 referring to Fig. 23.

[0095] Referring to Fig. 23, first of all, at step 240, the correction coefficient K is made the constant value KK of for example about 1.3. Subsequently, at step 241, the fuel injection time TAU is calculated on the basis of the following equation:

$$TAU = TP \circ K$$

[0096] Accordingly, when the decision of deterioration is started, the feedback control of the air-fuel ratio is stopped, and the air-fuel ratio of the air-fuel mixture is made rich. Subsequently, at step 242, the amount of release NOXD of NO_x released from the NO_x absorbent 18 per unit time is calculated on the basis of the following equation:

$$NOXD = f \circ (K - 1.0) \circ TP \circ N$$

[0097] Subsequently, at step 243, the amount of release VNO_x of NO_x actually released from the NO_x absorbent 18 is calculated on the basis of the following equation. Note that, in the following equation, Δt represents the interval of the time interruption.

$$VNO_x = VNO_x + NOXD \circ \Delta t$$

[0098] Subsequently, at step 244, it is determined whether or not the current value I of the O_2 sensor 22 becomes lower than the predetermined constant value α (Fig. 11). When I becomes smaller than α, the processing routine proceeds to step 245, at which by multiplying a constant value larger than 1.0, for example, 1.1, with VNO_x, the decision level SAT ($= 1.1 \circ VNO_x$) is calculated. In this case, as mentioned before, VNO_x represents the maximum amount of absorption of NO_x, that is, the degree of deterioration of the NO_x absorbent 18. Subsequently, at step 246, on the basis of

the maximum amount of absorption of NO_x VNO_x, a cycle TL making the air-fuel ratio of the air-fuel mixture rich is calculated from the relationship shown in Fig. 19A, and then at step 247, the rich time TR of the air-fuel mixture is calculated from the relationship shown in Fig. 19B on the basis of the maximum amount of absorption of NO_x VNO_x.

[0099] Subsequently, at step 248, it is determined whether or not the maximum amount of absorption of NO_x VNO_x becomes lower than the predetermined minimum value MIN. When VNO_x becomes smaller than MIN, the processing routine proceeds to step 249, at which the alarm lamp 25 is turned on. Subsequently, at step 250, the decision of deterioration flag is reset. When the decision of deterioration flag is reset, the air-fuel ratio of the air-fuel mixture is changed to the air-fuel ratio in accordance with the operating state at that time, usually lean. Subsequently, at step 251, the VNO_x and ΣNOX are made zero.

[0100] As mentioned above, according to the present invention, when the amount of NO_x, actually absorbed in the NO_x, absorbent 18 becomes the predetermined set value, the action of releasing NO_x from the NO_x, absorbent is carried out. Accordingly, it is possible to prevented the NO_x from not being absorbed into the NO_x absorbent and being released into the atmosphere or the amount of the fuel consumption being increased as in the conventional case.

[0101] Further, in the present invention, the amount of NO_x actually absorbed in the NO_x absorbent is detected, and the degree of deterioration of the NO_x absorbent is decided on the basis of this, so the degree of deterioration of the NO_x absorbent can be correctly decided.

Claims

1. An exhaust purification device of an engine having an exhaust passage, comprising:

   an NOx absorbent (18) arranged in the exhaust passage (16, 21), said NOx absorbent (18) absorbing NOx therein when an air-fuel ratio of exhaust gas flowing into the NOx absorbent (18) is lean and releasing absorbed NOx therefrom when the air-fuel ratio of the exhaust gas flowing into the NOx absorbent (18) becomes rich;
   estimating means for estimating an amount of NOx absorbed in the NOx absorbent (18) to obtain an estimated amount of NOx stored in the NOx absorbent (18);
   air-fuel ratio detecting means (22) arranged in the exhaust passage (16, 21) downstream of the NOx absorbent (18) for generating an output signal indicating an air-fuel ratio of exhaust gas which flows out from the NOx absorbent (18);
   NOx amount calculating means for calculating an entire actual amount of absorbed NOx stored in the NOx absorbent (18) on the basis of the output signal of said air-fuel ratio detecting means (22) when the air-fuel ratio of exhaust gas flowing into the NOx absorbent (18) is changed from lean to rich so as to release NOx from the NOx absorbent (18);
   correction value calculating means for calculating a correction value for said estimated amount of NOx, wherein said correction value is a value by which said estimated amount of NOx is corrected when the air-fuel ratio of exhaust gas flowing into the NOx absorbent (18) is changed from lean to rich so that the corrected estimated amount of NOx represents the entire actual amount of absorbed NOx;
   control means for controlling the air-fuel ratio of exhaust gas flowing into the NOx absorbent (18) to change the air-fuel ratio of exhaust gas flowing into the NOx absorbent (18) from lean to rich to release NOx from the NOx absorbent (18) when said corrected estimated amount of NOx corrected by said correction value exceeds a predetermined amount.

2. An exhaust purification device as set forth in claim 1, wherein the NOx absorbent (18) contains at least one component selected from alkali metals consisting of potassium, sodium, lithium and cesium, alkali earth metals consisting of barium and calcium, and rare earth metals consisting of lanthanum and yttrium and platinum.

3. An exhaust purification device as set forth in claim 1, wherein said estimation means increases an NOx storage amount in accordance with the amount of absorption of NOx determined according to the engine operating state when the air-fuel ratio of the exhaust gas flowing into the NOx absorbent (18) is lean, and then decreases the NOx storage amount in accordance with the NOx releasing amount determined according to the engine operating state when the air-fuel ratio of the exhaust gas flowing into the NOx absorbent (18) is rich, thereby to find said NOx estimated amount.

4. An exhaust purification device as set forth in claim 3, wherein said amount of absorption of NOx determined according to the engine operating state is a function of the engine speed and the engine load.

5. An exhaust purification device as set forth in claim 3, wherein said NOx releasing amount determined according to the engine operating state is proportional to the excess fuel amount.

6. An exhaust purification device as set forth in claim 1, wherein said air-fuel ratio detection means generates an output signal indicating that the air-fuel ratio is slightly lean during a period for which the NOx is released from the NOx absorbent (18) after the air-fuel ratio of the exhaust gas flowing into the NOx absorbent (18) is changed from lean to rich and generates an output signal indicating that the air-fuel ratio is rich when the NOx releasing action from the NOx absorbent (18) is completed.

7. An exhaust purification device as set forth in claim 6, wherein said air-fuel ratio detection means comprises an air-fuel ratio detection sensor (20, 22) which increases its output current proportional to the increase of the air-fuel ratio.

8. An exhaust purification device as set forth in claim 6, wherein said NOx amount calculation means decreases the NOx storage amount in accordance with the NOx releasing amount determined according to the engine operating state during a period from when the air-fuel ratio of the exhaust gas flowing into the NOx absorbent (18) is changed from lean to rich to when said air-fuel ratio detection means generates the output signal indicating that the air-fuel ratio is rich, and thereby said entire amount of NOx stored in the NOx absorbent (18) is calculated.

9. An exhaust purification device as set forth in claim 8, wherein said NOx releasing amount determined according to the engine operating state is proportional to the excess fuel amount.

10. An exhaust purification device as set forth in claim 1, wherein when defining the estimated amount of NOx estimated by said estimation means as ΣNOX and defining the correction value calculated by said correction value calculation means as KX, the estimated amount of NOx ΣNKX corrected by said correction value is represented by the following equation:

$$\Sigma NKX = KX \circ \Sigma NOX$$

11. An exhaust purification device as set forth in claim 10, wherein when defining said entire amount of NOx calculated by said NOx amount calculation means as XNOx, said correction value KX is updated on the basis of the following equation:

$$KX = KX \circ XNOx/\Sigma NKX$$

12. An exhaust purification device as set forth in claim 11, wherein when the difference between the estimated amount of NOx ΣNKX corrected by said correction value and said entire amount of NOx XNOx is larger than a predetermined value, said correction value KX is updated.

13. An exhaust purification device as set forth in claim 1, wherein the predetermined amount in said control means is smaller than the maximum amount of absorption of NOx of the NOx absorbent (18).

14. An exhaust purification device as set forth in claim 1, wherein the predetermined amount in said control means is larger than the maximum amount of absorption of NOx of the NOx absorbent (18), and deterioration of the NOx absorbent (18) on the basis of said entire amount of NOx calculated by said NOx amount calculation means is provided.

15. An exhaust purification device as set forth in claim 14, wherein said predetermined amount is made larger than said entire amount of NOx by exactly a predetermined proportion.

16. An exhaust purification device as set forth in claim 15, wherein said proportion is larger than 1.0 and smaller than 1.3.

17. An exhaust purification device as set forth in claim 14, wherein when said entire amount of NOx becomes smaller than the predetermined amount, said deterioration decision means decides that the NOx absorbent (18) is deteriorated.

18. An exhaust purification device as set forth in claim 1, wherein said NOx amount calculation means comprises first NOx amount calculation means for calculating said entire amount of NOx for only releasing NOx from the NOx absorbent (18) and second NOx amount calculation means for calculating said entire amount of NOx for releasing NOx from the NOx absorbent (18) and detecting the degree of deterioration of the NOx absorbent (18), when the entire amount of NOx is calculated by the first NOx amount calculation means, the predetermined amount in said control means is made smaller than the maximum amount of absorption of NOx of the NOx absorbent (18), and when thee entire amount of NOx is calculated by the second NOx amount calculation means, the predetermined amount in said control means is made larger than the maximum amount of absorption of NOx of the NOx absorbent (18).

19. An exhaust purification device as set forth in claim 18, wherein the frequency of that the entire amount of NOx is calculated by the second NOx amount calculation means is lower than the frequency of that the entire amount of NOx is calculated by the first

NOx amount calculation means.

20. An exhaust purification device as set forth in claim 18, wherein the entire amount of NOx calculated by said second NOx amount calculation means represents the maximum amount of absorption of NOx VNOx of the NOx absorbent (18), when the entire amount of NOx is calculated by the first NOx amount calculation means, the predetermined amount is made smaller than the maximum amount of absorption of NOx VNOx by exactly the predetermined proportion, and when the entire amount of NOx is calculated by the second NOx amount calculation means, the predetermined amount is made larger than the maximum amount of absorption of NOx VNOx by exactly the predetermined proportion.

21. An exhaust purification device as set forth in claim 20, wherein deterioration decision means is provided for deciding the degree of deterioration of the NOx absorbent (18) on the basis of said maximum amount of absorption of NOx VNOx.

Patentansprüche

1. Abgasreinigungsvorrichtung für eine Brennkraftmaschine mit einem Auslaßkanal, die aufweist:

- ein NO_x-Absorptionsmittel (18), das in dem Auslaßkanal (16, 21) angeordnet ist, wobei das NO_x-Absorptionsmittel (18) NO_x absorbiert, wenn ein Luft-Kraftstoff-Verhältnis des in das NO_x-Absorptionsmittel (18) einströmenden Abgases mager ist, und absorbiertes NO_x aus diesem freisetzt, wenn das in das NO_x-Absorptionsmittel (18) einströmende Abgas fett ist,
- eine Schätzvorrichtung zum Schätzen einer in dem NO_x-Absorptionsmittel (18) absorbierten NO_x-Menge, um eine geschätzte NO_x-Menge, die in dem NO_x-Absorptionsmittel (18) gespeichert ist, zu erlangen,
- eine Luft-Kraftstoff-Verhältnis-Erfassungsvorrichtung (22), die in dem Auslaßkanal (16, 21) abgangsseitig des NO_x-Absorptionsmittels (18) angeordnet ist, um ein Ausgangssignal zu erzeugen, das ein Luft-Kraftstoff-Verhältnis des Abgases anzeigt, welches aus dem NO_x-Absorptionsmittel (18) aus-strömt,
- eine NO_x-Mengenberechnungsvorrichtung zum Berechnen einer tatsächlich absorbierten NO_x-Gesamtmenge, die in dem NO_x-Absorptionsmittel (18) gespeichert ist, auf der Grundlage des Ausgangssignals der Luft-Kraftstoff-Verhältnis-Erfas-sungsvorrichtung (22), wenn sich das Luft-Kraftstoff-Verhältnis des in das NO_x-Absorptionsmittel (18) einströmenden Abgases von mager nach fett verändert, um NO_x aus dem NO_x-Absorptionsmittel (18) freizusetzen,
- eine Korrekturwert-Berechnungsvorrichtung zum Berechnen eines Korrekturwerts für die geschätzte NO_x-Menge, wobei der Korrekturwert ein Wert ist, durch welchen die geschätzte NO_x-Menge korrigiert wird, wenn sich das Luft-Kraftstoff-Verhältnis des in das NO_x-Absorptionsmittel (18) einströmenden Abgases von mager nach fett verändert, so daß die korrigierte, geschätzte NO_x-Menge die tatsächlich absorbierte NO_x-Gesamtmenge darstellt, und
- eine Regelvorrichtung zum Regeln des Luft-Kraftstoff-Verhältnisses des in das No_x-Absorptionsmittel (18) einströmenden Abgases, um das Luft-Kraftstoff-Verhältnis des in das NO_x-Absorptionsmittel (18) einströmenden Abgases von mager nach fett zu verändern, um NO_x aus dem No_x-Absorptionsmittel (18) freizusetzen, wenn die durch den Korrekturwert korrigierte NO_x-Schätzmenge eine vorbestimmte Menge übersteigt.

2. Abgasreinigungsvorrichtung gemäß Anspruch 1, wobei das NO_x-Absorptionsmittel (18) mindestens einen Bestandteil enthält, der aus Alkalimetallen ausgewählt ist, die Kalium, Natrium, Lithium und Caesium aufweisen, aus Alkalierdmetallen, die Barium und Calcium aufweisen, und Seltenerdmetallen, die Lanthan und Yttrium und Platin aufweisen.

3. Abgasreinigungsvorrichtung gemäß Anspruch 1, wobei die Schätzvorrichtung eine No_x-Speichermenge gemäß der NO_x-Absorptionsmenge erhöht, die gemäß dem Betriebszustand der Brennkraftmaschine bestimmt ist, wenn das Luft-Kraftstoff-Verhältnis des in das NO_x-Absorptionsmittel (18) einströmenden Abgases mager ist, und dann die NO_x-Speichermenge gemäß der NO_x-Freisetzungsmenge vermindert, die gemäß dem Betriebszustand der Brennkraftmaschine bestimmt ist, wenn das Luft-Kraftstoff-Verhältnis des in das NO_x-Absorptionsmittel (18) einströmende Abgas fett ist, um dadurch die NO_x-Schätzmenge zu erhalten.

4. Abgasreinigungsvorrichtung gemäß Anspruch 3, wobei die NO_x-Absorptionsmenge, die gemäß dem Betriebszustand der Brennkraftmaschine bestimmt ist, eine Funktion der Drehzahl der Brennkraftmaschine und der Belastung der Brennkraftmaschine ist.

5. Abgasreinigungsvorrichtung gemäß Anspruch 3, wobei die gemäß dem Betriebszustand der Brennkraftmaschine bestimmte NO_x-Freisetzungsmenge proportional der überschüssigen Kraftstoffmenge ist.

6. Abgasreinigungsvorrichtung gemäß Anspruch 1, wobei die Luft-Kraftstoff-Verhältnis-Erfassungsvorrichtung ein Ausgangssignal erzeugt, das anzeigt, daß das Luft-Kraftstoff-Verhältnis während einer Periode, in welcher das NO_x aus dem NO_x-Absorptionsmittel (18) freigesetzt wird, geringfügig mager ist, nachdem sich das Luft-Kraftstoff-Verhältnis des in das NO_x-Absorptionsmittel (18) einströmende Abgas von mager nach fett verändert, und ein Ausgangssignal erzeugt, das anzeigt, daß das Luft-Kraftstoff-Verhältnis fett ist, wenn der NO_x-Freisetzungsvorgang aus dem NO_x-Absorptionsmittel (18) abgeschlossen ist.

7. Abgasreinigungsvorrichtung gemäß Anspruch 6, wobei die Luft-Kraftstoff-Verhältnis-Erfassungsvorrichtung einen Luft-Kraftstoff-Verhältnis-Erfassungssensor (20, 22) aufweist, dessen Ausgangsstrom proportional zu der Vergrößerung des Luft-Kraftstoff-Verhältnisses ansteigt.

8. Abgasreinigungsvorrichtung gemäß Anspruch 6, wobei die NO_x-Mengenberechnungsvorrichtung die NO_x-Speichermenge gemäß der NO_x-Freisetzungsmenge vermindert, die gemäß dem Betriebszustand der Brennkraftmaschine während einer Periode von dem Zeitpunkt an bestimmt ist, wenn sich das Luft-Kraftstoff-Verhältnis des in das NO_x-Absorptionsmittel (18) einströmenden Abgases von mager nach fett verändert, bis zu dem Zeitpunkt, wenn die Luft-Kraftstoff-Verhältnis-Erfassungsvorrichtung das Ausgangssignal erzeugt, das anzeigt, daß das Luft-Kraftstoff-Verhältnis fett ist, und dabei die in dem NO_x-Absorptionsmittel (18) gespeicherte NO_x-Gesamtmenge berechnet.

9. Abgasreinigungsvorrichtung gemäß Anspruch 8, wobei die gemäß dem Betriebszustand der Brennkraftmaschine bestimmte NO_x-Freisetzungsmenge proportional der überschüssigen Kraftstoffmenge ist.

10. Abgasreinigungsvorrichtung gemäß Anspruch 1, wobei dann, wenn die durch die Schätzvorrichtung geschätzte NO_x-Schätz-menge als ΣNOX definiert ist und der durch die Korrekturwert-Berechnungsvorrichtung berechnete Korrekturwert als KX definiert ist, die durch den Korrekturwert korrigierte NO_x-Schätzmenge ΣNKX durch die folgende Gleichung dargestellt wird:

$$\Sigma NKX = KX \cdot \Sigma NOX.$$

11. Abgasreinigungsvorrichtung gemäß Anspruch 10, wobei dann, wenn die durch die NO_x-Mengenberechnungsvorrichtung berechnete NO_x-Gesamtmenge als XNO_x definiert ist, der Korrekturwert KX auf der Grundlage der folgenden Gleichung aktualisiert wird:

$$KX = KX \cdot XNO_x / \Sigma NKX.$$

12. Abgasreinigungsvorrichtung gemäß Anspruch 11, wobei dann, wenn die Differenz zwischen der durch den Korrekturwert korrigierten NO_x-Schätzmenge ΣNKX und der NO_x-Gesamtmenge XNO_x größer als ein vorbestimmter Wert ist, der Korrekturwert KX aktualisiert wird.

13. Abgasreinigungsvorrichtung gemäß Anspruch 1, wobei die in der Regelvorrichtung vorbestimmte Menge kleiner als die maximale NO_x-Absorptionsmenge des NO_x-Absorptionsmittels (18) ist.

14. Abgasreinigungsvorrichtung gemäß Anspruch 1, wobei die in der Regeleinrichtung vorbestimmte Menge größer als die maximale NO_x-Absorptionsmenge des NO_x-Absorptionsmittels (18) ist und die Verschlechterung des NO_x-Absorptionsmittels (18) auf der Grundlage der durch die NO_x-Mengenberechnungsvor-richtung berechneten NO_x-Gesamtmenge ausgegeben wird.

15. Abgasreinigungsvorrichtung gemäß Anspruch 14, wobei die vorbestimmte Menge in einem genau vorbestimmten Verhältnis größer als die NO_x-Gesamtmenge ausgebildet wird.

16. Abgasreinigungsvorrichtung gemäß Anspruch 15, wobei das Verhältnis größer als 1,0 und kleiner als 1,3 ist.

17. Abgasreinigungsvorrichtung gemäß Anspruch 14, wobei dann, wenn die NO_x-Gesamtmenge kleiner als die vorbestimmte Menge ist, die Verschlechterungsbeurteilungsvorrichtung beurteilt, daß das NO_x-Absorptionsmittel (18) verschlechtert ist.

18. Abgasreinigungsvorrichtung gemäß Anspruch 1, wobei die NO_x-Mengenberechnungsvorrichtung eine erste NO_x-Mengenberech-nungseinrichtung zum Berechnen der NO_x-Gesamtmenge nur zur NO_x-Freisetzung aus dem NO_x-Absorptionsmittel (18) aufweist und eine zweite NO_x-Mengenberechnungseinrichtung zum Berechnen der NO_x-Gesamtmenge zur NO_x-Freisetzung aus dem NO_x-Absorptionsmittel (18) und zum Erfassen des Verschlechterungsgrads des NO_x-Absorptionsmittels (18), wenn die NO_x-Gesamtmenge durch die erste NO_x-Mengenberechnungseinrichtung berechnet ist, die vorbestimmte Menge in der Regelvorrichtung kleiner als die maximale NO_x-Absorptionsmenge des NO_x-Absorptionsmittels (18) ausgebildet wird, und wenn die NO_x-Gesamtmenge durch

die zweite NO_x-Mengenberechnungsvorrichtung berechnet ist, die vorbestimmte Menge in der Regelvorrichtung größer als die maximale NO_x-Absorptionsmenge des NO_x-Absorptionsmittels (18) ausgebildet wird.

19. Abgasreinigungsvorrichtung gemäß Anspruch 18, wobei die Häufigkeit mit der die NO_x-Gesamtmenge durch die zweite NO_x-Mengenberechnungseinrichtung berechnet wird, kleiner als die Häufigkeit ist, mit der die NO_x-Gesamtmenge durch die erste NO_x-Mengenberechnungsvorrichtung berechnet wird.

20. Abgasreinigungsvorrichtung gemäß Anspruch 18, wobei die durch die zweite NO_x-Mengenberechnungseinrichtung berechnete NO_x-Gesamtmenge die maximale NO_x-Absorptionsmenge VNO_x des NO_x-Absorptionsmittels (18) darstellt, wenn die NO_x-Gesamtmenge durch die erste NO_x-Mengenberechnungseinrichtung berechnet ist, die vorbestimmte Menge in genau dem vorbestimmten Verhältnis kleiner als die maximale NO_x-Absorptionsmenge VNO_x ausgebildet wird, und wenn die NO_x-Gesamtmenge durch die zweite NO_x-Mengenberechnungseinrichtung berechnet wird, die vorbestimmte Menge in genau dem vorbestimmten Verhältnis größer als die maximale NO_x-Absorptionsmenge VNO_x ausgebildet wird.

21. Abgasreinigungsvorrichtung gemäß Anspruch 20, wobei die Verschlechterungsbeurteilungsvorrichtung zum Beurteilen des Verschlechterungsgrads des NO_x-Absorptionsmittels (18) auf der Grundlage der maximalen NO_x-Absorptionsmenge VNO_x vorgesehen ist.

Revendications

1. Un dispositif d'épuration d'échappement d'un moteur ayant un passage d'échappement, comprenant :

   un absorbant (18) de NOx agencé dans le passage (16, 21) d'échappement, ledit absorbant (18) de NOx absorbant du NOx quand le rapport air-carburant du gaz d'échappement s'écoulant dans l'absorbant (18) de NOx est pauvre et libérant de l'absorbant le NOx absorbé lorsque le rapport air-carburant du gaz d'échappement s'écoulant dans l'absorbant (18) de NOx devient riche ;
   des moyens d'estimation pour estimer la quantité de NOx absorbée dans l'absorbant (18) de NOx pour obtenir une quantité estimée de NOx accumulée dans l'absorbant (18) de NOx ;
   des moyens (22) de mesure du rapport air-carburant agencés dans le passage (16, 21) d'échappement en aval par rapport à l'absorbant (18) de NOx pour générer un signal de sortie indiquant un rapport air-carburant du gaz d'échappement qui s'écoule en dehors de l'absorbant (18) de NOx ;
   des moyens de calcul de la quantité de NOx pour calculer la quantité totale effective de NOx absorbée, stockée dans l'absorbant (18) de NOx sur la base du signal de sortie desdits moyens (22) de mesure du rapport air-carburant quand le rapport air-carburant des gaz d'échappement s'écoulant dans l'absorbant (18) de NOx était pauvre et qu'il devient riche, de façon à libérer le NOx de l'absorbant (18) de NOx ;
   des moyens calculant la valeur de correction pour calculer la valeur de correction pour ladite quantité estimée de NOx, ladite valeur de correction étant une valeur par laquelle ladite quantité estimée de NOx est corrigée quand le rapport air-carburant des gaz d'échappement s'écoulant dans l'absorbant (18) de NOx était pauvre et qu'il devient riche, de telle manière que la quantité estimée corrigée de NOx représente la quantité totale effective de NOx absorbée ;
   des moyens de contrôle pour asservir le rapport air-carburant des gaz d'échappement s'écoulant dans l'absorbant (18) de NOx pour modifier le rapport air-carburant pauvre des gaz d'échappement s'écoulant dans l'absorbant (18) de NOx en un rapport riche pour libérer le NOx de l'absorbant (18) de NOx quand ladite quantité estimée corrigée de NOx, corrigée par ladite valeur de correction, excède une quantité prédéterminée.

2. Un dispositif d'épuration d'échappement selon la revendication 1, dans lequel l'absorbant (18) de NOx contient au moins un constituant sélectionné parmi les métaux alcalins se composant de potassium, de sodium, de lithium et de césium, parmi les métaux alcalins ou terreux se composant de baryum et de calcium, et parmi les métaux de terres rares se composant de lanthane, d'yttrium et de platine.

3. Un dispositif d'épuration de l'échappement selon la revendication 1, dans lequel lesdits moyens d'estimation augmentent la quantité de NOx accumulée en correspondance à la quantité d'absorption de NOx déterminé en fonction de l'état de fonctionnement du moteur quand le rapport air-carburant des gaz d'échappement s'écoulant dans l'absorbant (18) de NOx est pauvre et ensuite diminuent la quantité d'accumulation de NOx en fonction de la quantité de NOx libérée, déterminée en fonction de

l'état de fonctionnement du moteur quand le rapport air-carburant des gaz d'échappement s'écoulant dans l'absorbant (18) de NOx est riche, afin de trouver ladite quantité estimée de NOx.

4. Un dispositif d'épuration de l'échappement selon la revendication 3, dans lequel ladite quantité d'absorption de NOx déterminée conformément à l'état de fonctionnement du moteur est une fonction de la vitesse du moteur et de la charge du moteur.

5. Un dispositif d'épuration de l'échappement selon la revendication 3, dans lequel ladite quantité de NOx libérée, déterminée en fonction de l'état de fonctionnement du moteur, est proportionnelle à la quantité de carburant en excès.

6. Un dispositif d'épuration de l'échappement selon la revendication 1, dans lequel lesdits moyens de mesure du rapport air-carburant génèrent un signal de sortie indiquant que le rapport air-carburant est légèrement pauvre durant une période pendant laquelle le NOx est libéré de l'absorbant (18) de NOx après que le rapport air-carburant des gaz d'échappement s'écoulant dans l'absorbant (18) de NOx ait commuté de pauvre à riche et lesdits moyens de mesure génèrent un signal de sortie indiquant que le rapport air-carburant est riche quand l'action de libération du NOx de l'absorbant (18) de NOx est achevée.

7. Un dispositif d'épuration d'échappement selon la revendication 6, dans lequel lesdits moyens de mesure du rapport air-carburant comprennent un capteur (20, 22) de mesure du rapport air-carburant qui augmente son courant de sortie proportionnellement à l'augmentation du rapport air-carburant.

8. Un dispositif d'épuration de l'échappement selon la revendication 6, dans lequel lesdits moyens de calcul de la quantité de NOx font baisser la quantité d'accumulation de NOx conformément à la quantité de NOx libérée déterminée en fonction de l'état de fonctionnement du moteur pendant une période s'étendant depuis que le rapport air-carburant est commuté de pauvre à riche et jusqu'à ce que lesdits moyens de mesure du rapport air-carburant génèrent le signal de sortie indiquant que le rapport air-carburant est riche, et de façon que ladite quantité totale de NOx accumulée dans l'absorbant (18) de NOx soit calculée.

9. Un dispositif d'épuration de l'échappement selon la revendication 8, dans lequel ladite quantité libérée de NOx déterminée en fonction de l'état de fonctionnement du moteur est proportionnelle à la quantité de carburant en excès.

10. Un dispositif d'épuration de l'échappement suivant la revendication 1, dans lequel, lors de la détermination de la quantité estimée de NOx estimée par lesdits moyens d'estimation tels que ΣNOx et lors de la détermination de la valeur de correction calculée par lesdits moyens de calcul de la valeur de correction telle que KX, la quantité estimée de Nox ΣNKX corrigée par ladite valeur de correction est représentée par l'équation suivante :

$$\Sigma NKX = KX \circ \Sigma NOX$$

11. Un dispositif d'épuration de l'échappement selon la revendication 10, dans lequel, lors de la détermination de ladite quantité totale de NOx calculée par lesdits moyens de calcul de la quantité de NOx telle que XNOx, ladite valeur de correction KX est actualisée à partir de l'équation suivante :

$$KX = KX \circ XNOx/\Sigma NKX$$

12. Un dispositif d'épuration de l'échappement selon la revendication 11, dans lequel ladite valeur de correction KX est actualisée, quand la différence entre la quantité estimée de NOx ΣNKX corrigée par ladite valeur de correction et ladite quantité totale de NOx XNOx est supérieure à une valeur prédéterminée.

13. Un dispositif d'épuration d'échappement selon la revendication 1, dans lequel la quantité prédéterminée dans lesdits moyens de contrôle est plus petite que la quantité maximum d'absorption de NOx par l'absorbant (18) de NOx.

14. Un dispositif d'épuration d'échappement selon la revendication 1, dans lequel la quantité prédéterminée dans lesdits moyens de contrôle est plus grande que la quantité maximum d'absorption de NOx dans l'absorbant (18) de Nox, et dans lequel la détérioration de l'absorbant (18) de NOx est prévue sur la base de ladite quantité totale de NOx calculée par lesdits moyens de calcul de la quantité de NOx.

15. Un dispositif d'épuration d'échappement selon la revendication 14, dans lequel ladite quantité prédéterminée est plus grande que ladite quantité totale de NOx exactement dans une proportion prédéterminée.

16. Un dispositif d'épuration d'échappement selon la revendication 15, dans lequel ladite proportion est plus grande que 1,0 et plus petite que 1,3.

17. Un dispositif d'épuration d'échappement selon la revendication 14, dans lequel lesdits moyens de dé-

cision de détérioration décident que l'absorbant (18) de NOx est détérioré, lorsque ladite quantité totale de NOx devient plus petite que la quantité prédéterminée.

18. Un dispositif d'épuration d'échappement selon la revendication 1, dans lequel lesdits moyens de calcul de la quantité de NOx comprennent des premiers moyens de calcul de la quantité de NOx pour calculer ladite quantité totale de NOx seulement pour libérer du NOx de l'absorbant (18) de NOx et des deuxièmes moyens de calcul de la quantité de NOx pour calculer la quantité totale de NOx pour libérer du NOx de l'absorbant (18) de NOx et pour mesurer le degré de détérioration de l'absorbant (18) de NOx, la quantité prédéterminée dans ledits moyens de contrôle étant rendue plus petite que la quantité maximum d'absorption de NOx par l'absorbant (18) de NOx lorsque la quantité totale de NOx est calculée par les premiers moyens de calcul de la quantité de NOx, et la quantité prédéterminée dans lesdits moyens de contrôle étant rendue plus grande que la quantité maximum d'absorption de NOx par l'absorbant (18) de NOx lorsque la quantité totale de NOx est calculée par les deuxièmes moyens de calcul de la quantité de NOx.

19. Un dispositif d'épuration de l'échappement selon la revendication 18, dans lequel la fréquence de calcul de la quantité totale de NOx par les deuxièmes moyens de calcul de la quantité de NOx est plus petite que la fréquence de calcul de la quantité totale de NOx par les premiers moyens de calcul de la quantité de NOx.

20. Un dispositif d'épuration de l'échappement selon la revendication 18, dans lequel la quantité totale de NOx calculée par lesdits deuxièmes moyens de calcul de la quantité de NOx représente la quantité maximum d'absorption de NOx VNOx par l'absorbant (18) de NOx, la quantité prédéterminée étant plus petite que la quantité maximum d'absorption de NOx VNOx exactement dans la proportion déterminée lorsque la quantité totale de NOx est calculée par les premiers moyens de calcul de la quantité de NOx et la quantité prédéterminée étant plus grande que la quantité maximum d'absorption de NOx VNOx exactement dans la proportion prédéterminée lorsque la quantité totale de NOx est calculée par les deuxièmes moyens de calcul de la quantité de NOx.

21. Un dispositif d'épuration d'échappement selon la revendication 20, dans lequel des moyens de décision de la détérioration sont prévus pour décider le degré de détérioration de l'absorbant (18) de NOx sur la base de ladite quantité maximum d'absorption de NOx VNOx.

Fig.1

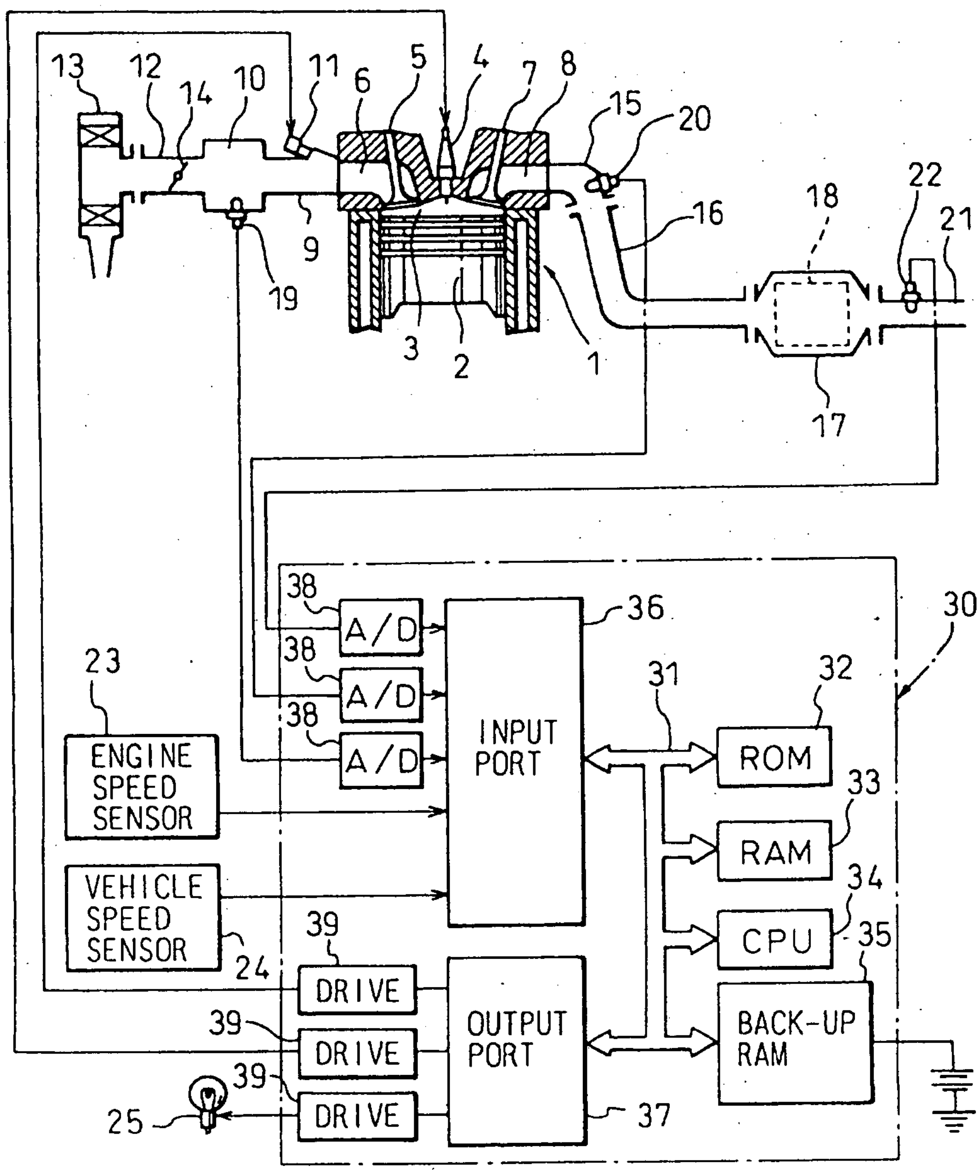

13
12
14
10
11
6
5
4
7
8
15
20
16
18
22
21
9
19
3
2
1
17
38
A/D
38
A/D
38
A/D
36
INPUT PORT
30
31
32
ROM
33
RAM
34
CPU
35
BACK-UP RAM
23
ENGINE SPEED SENSOR
VEHICLE SPEED SENSOR
24
39
DRIVE
39
DRIVE
39
DRIVE
OUTPUT PORT
37
25

Fig.2

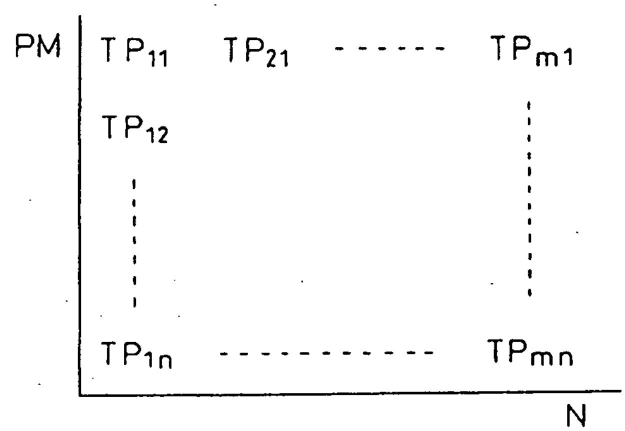


Fig.3

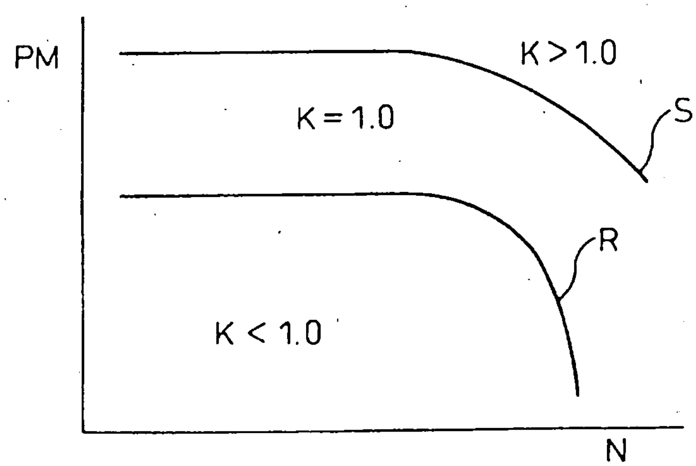


Fig.4

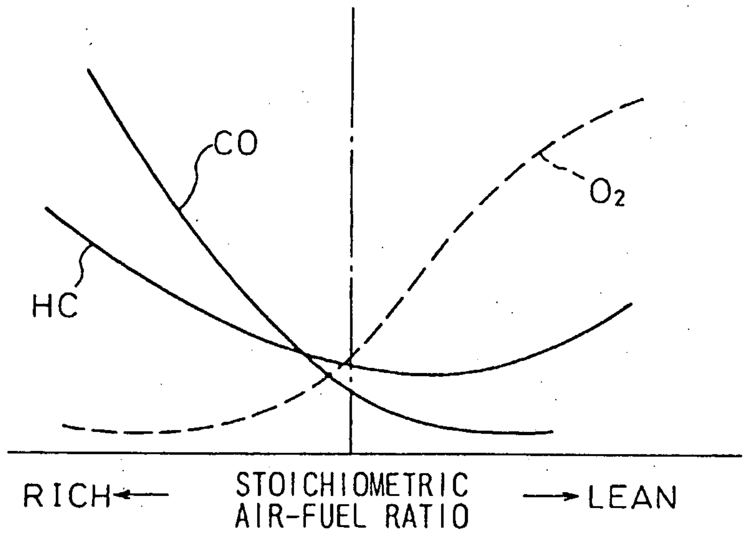


Fig.5A

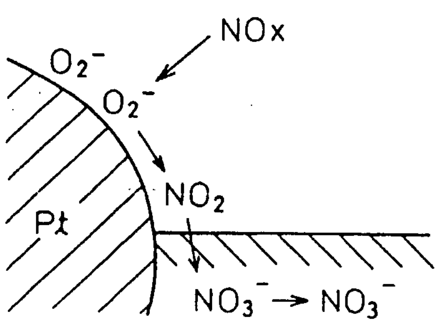


Fig.5B

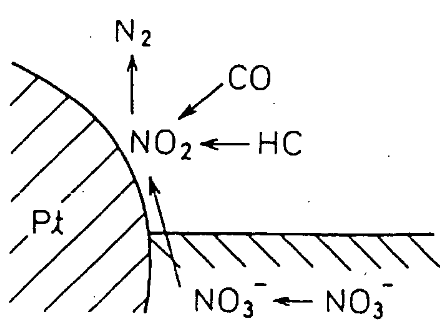


Fig.6

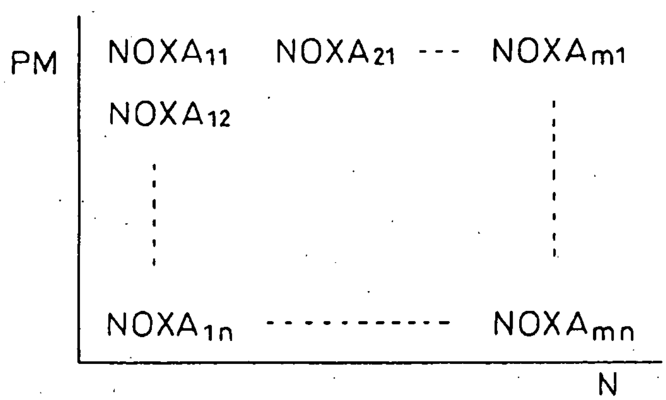


Fig.7

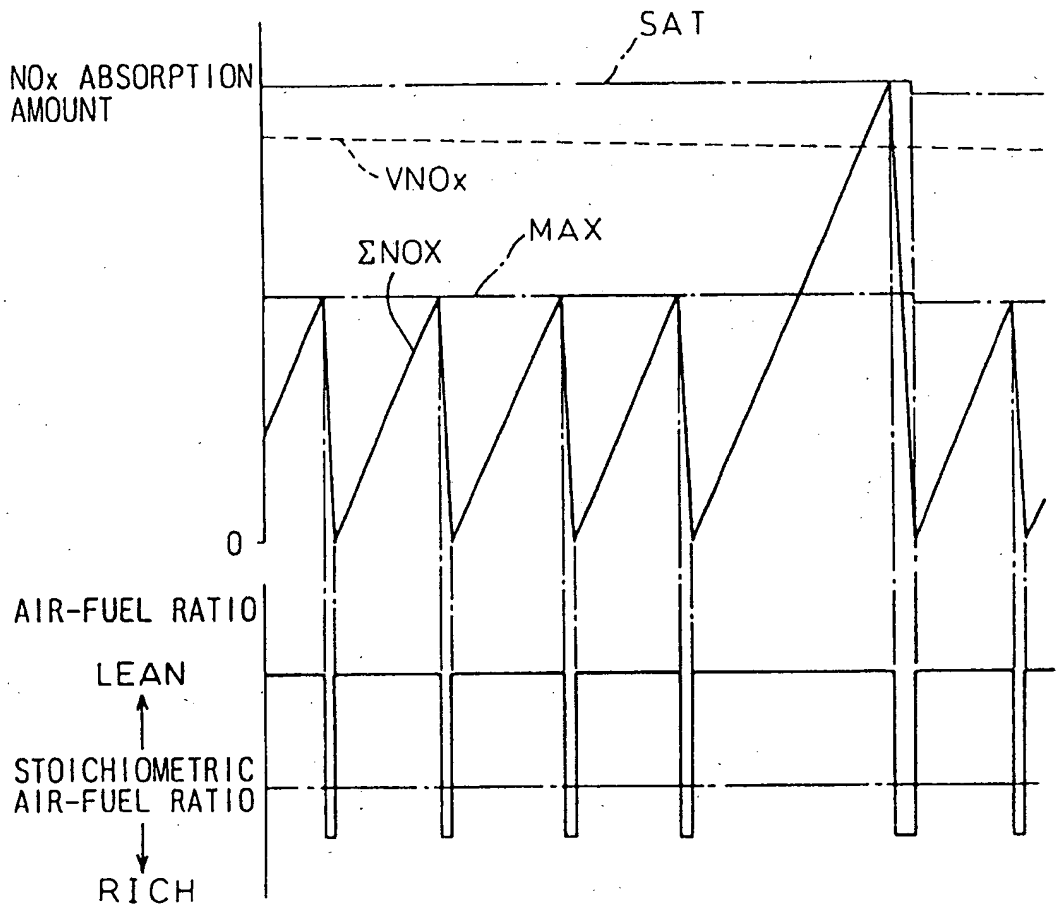

SAT
NOx ABSORPTION AMOUNT
VNOx
MAX
ΣNOX
0
AIR-FUEL RATIO
LEAN
STOICHIOMETRIC AIR-FUEL RATIO
RICH

Fig.8A

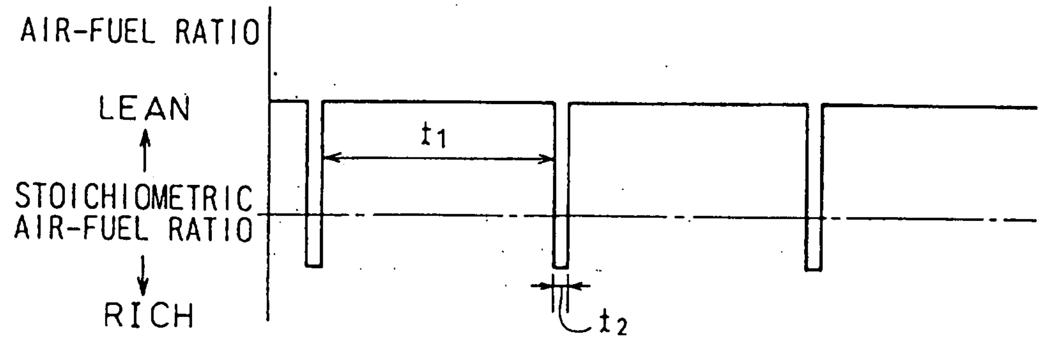

AIR-FUEL RATIO
LEAN
STOICHIOMETRIC AIR-FUEL RATIO
RICH
t1
t2

Fig.8B

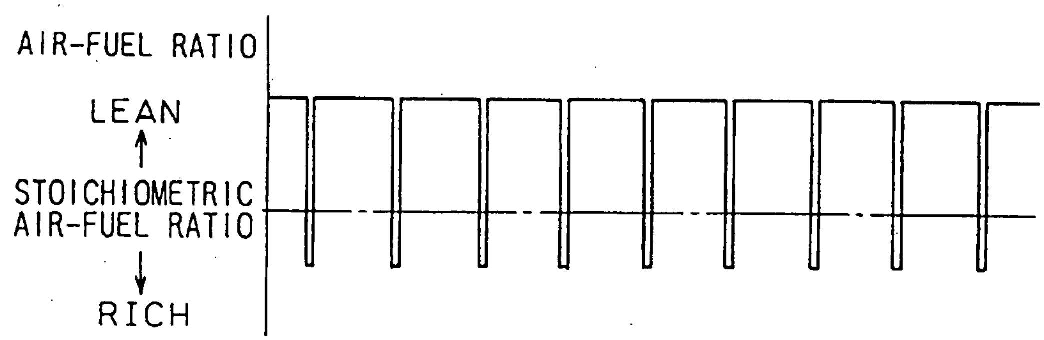

AIR-FUEL RATIO
LEAN
STOICHIOMETRIC AIR-FUEL RATIO
RICH

Fig.9

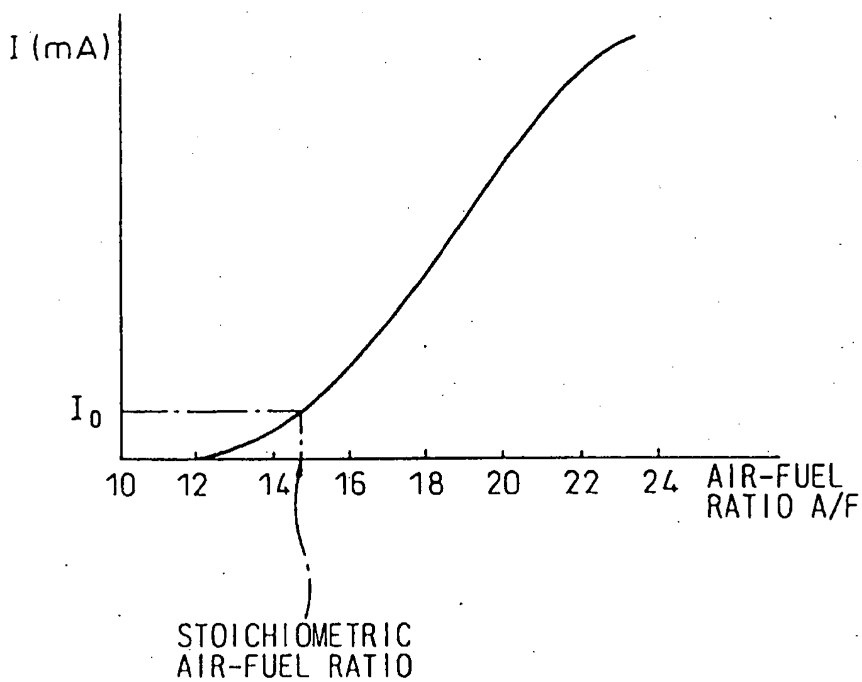

I (mA)
I_0
10
12
14
16
18
20
22
24
AIR-FUEL RATIO A/F
STOICHIOMETRIC AIR-FUEL RATIO

Fig.10

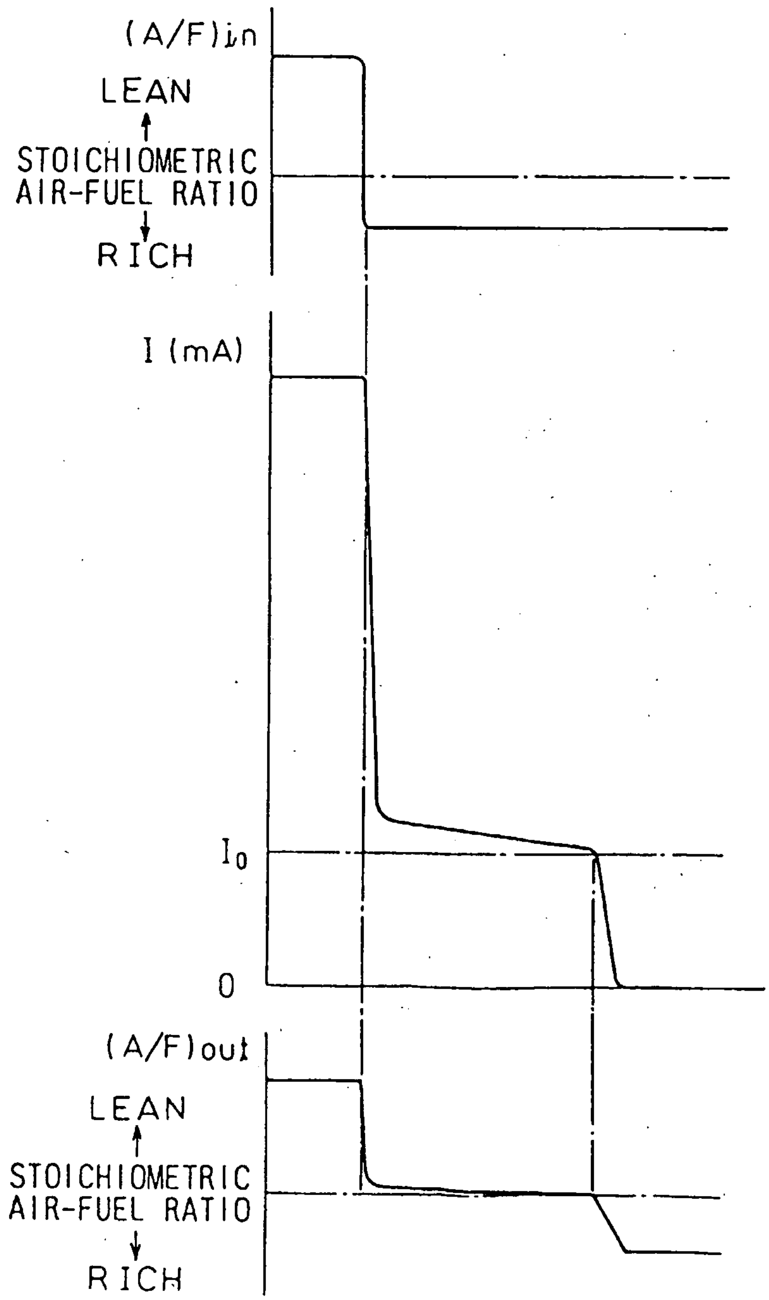
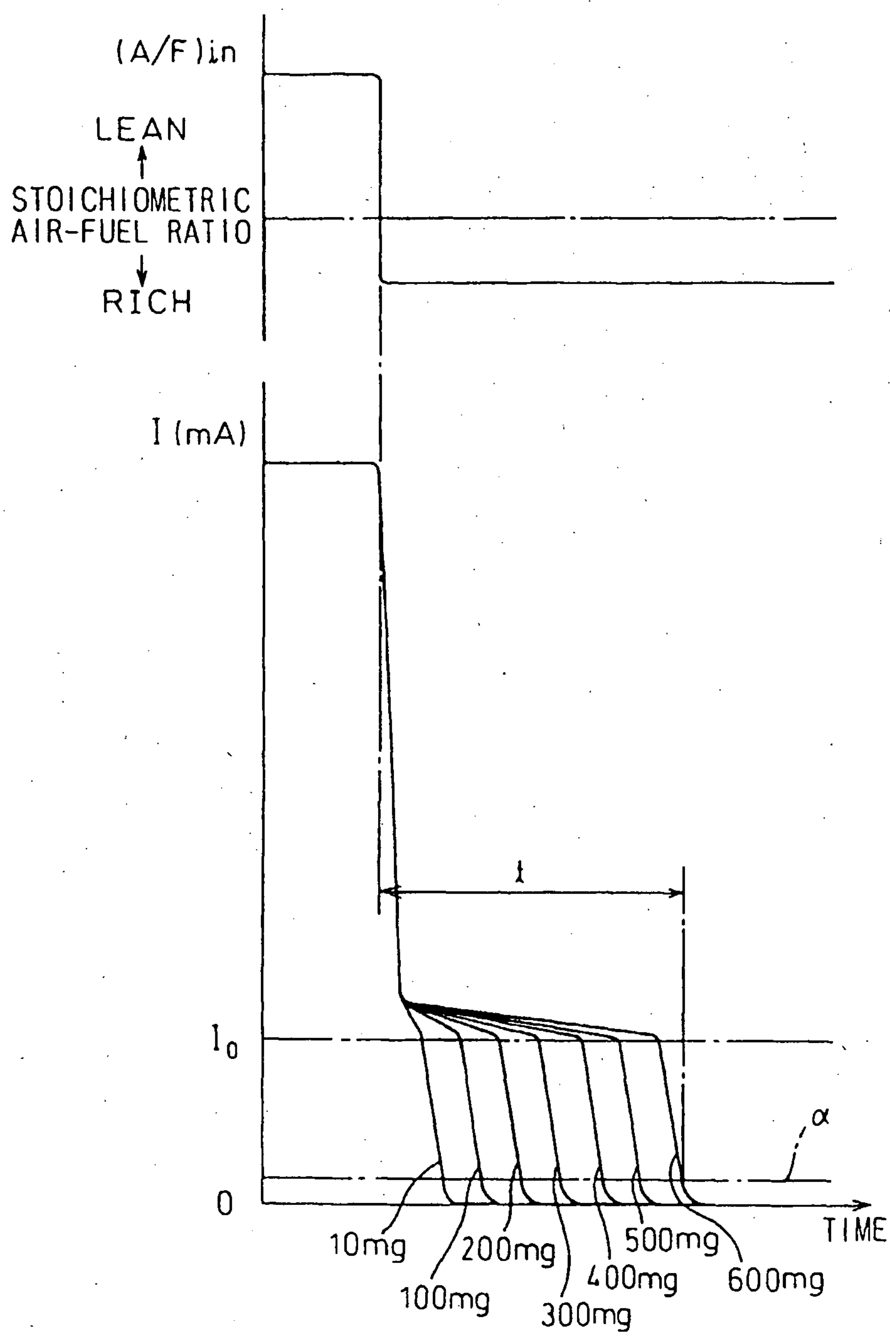

(A/F)in
LEAN
STOICHIOMETRIC
AIR-FUEL RATIO
RICH
I (mA)
I_0
0
(A/F)out
LEAN
STOICHIOMETRIC
AIR-FUEL RATIO
RICH

Fig.11



(A/F)in
LEAN
STOICHIOMETRIC AIR-FUEL RATIO
RICH
I (mA)
t
I_0
α
0
TIME
10mg
100mg
200mg
300mg
400mg
500mg
600mg

Fig.12

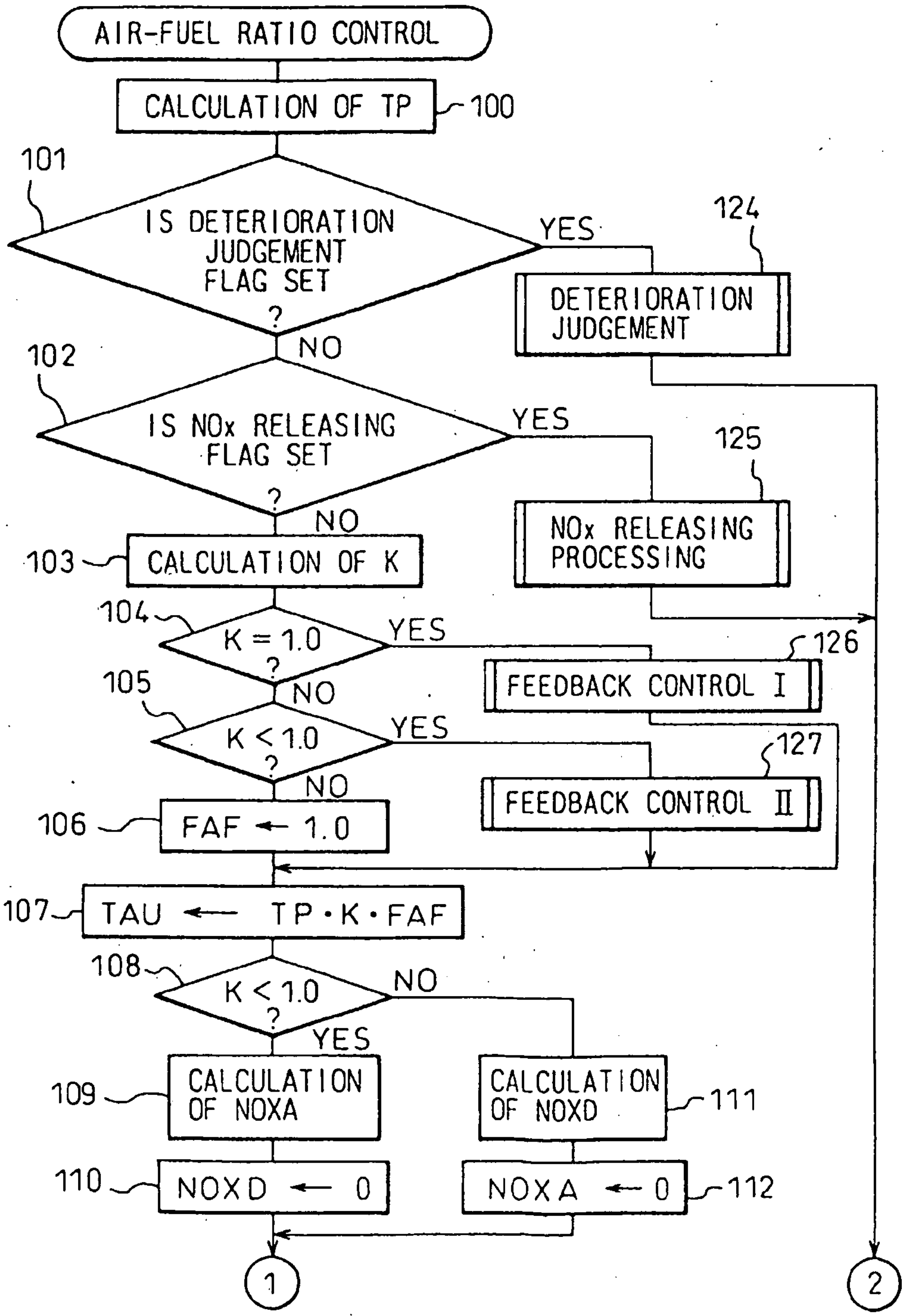

AIR-FUEL RATIO CONTROL
CALCULATION OF TP
100
101
IS DETERIORATION JUDGEMENT FLAG SET ?
YES
124
DETERIORATION JUDGEMENT
NO
102
IS NOx RELEASING FLAG SET ?
YES
125
NOx RELEASING PROCESSING
NO
103
CALCULATION OF K
104
K = 1.0 ?
YES
126
FEEDBACK CONTROL I
105
NO
K < 1.0 ?
YES
127
FEEDBACK CONTROL II
NO
106
FAF ← 1.0
107
TAU ← TP・K・FAF
108
K < 1.0 ?
NO
YES
109
CALCULATION OF NOXA
CALCULATION OF NOXD
111
110
NOXD ← 0
NOXA ← 0
112
1
2

Fig.13

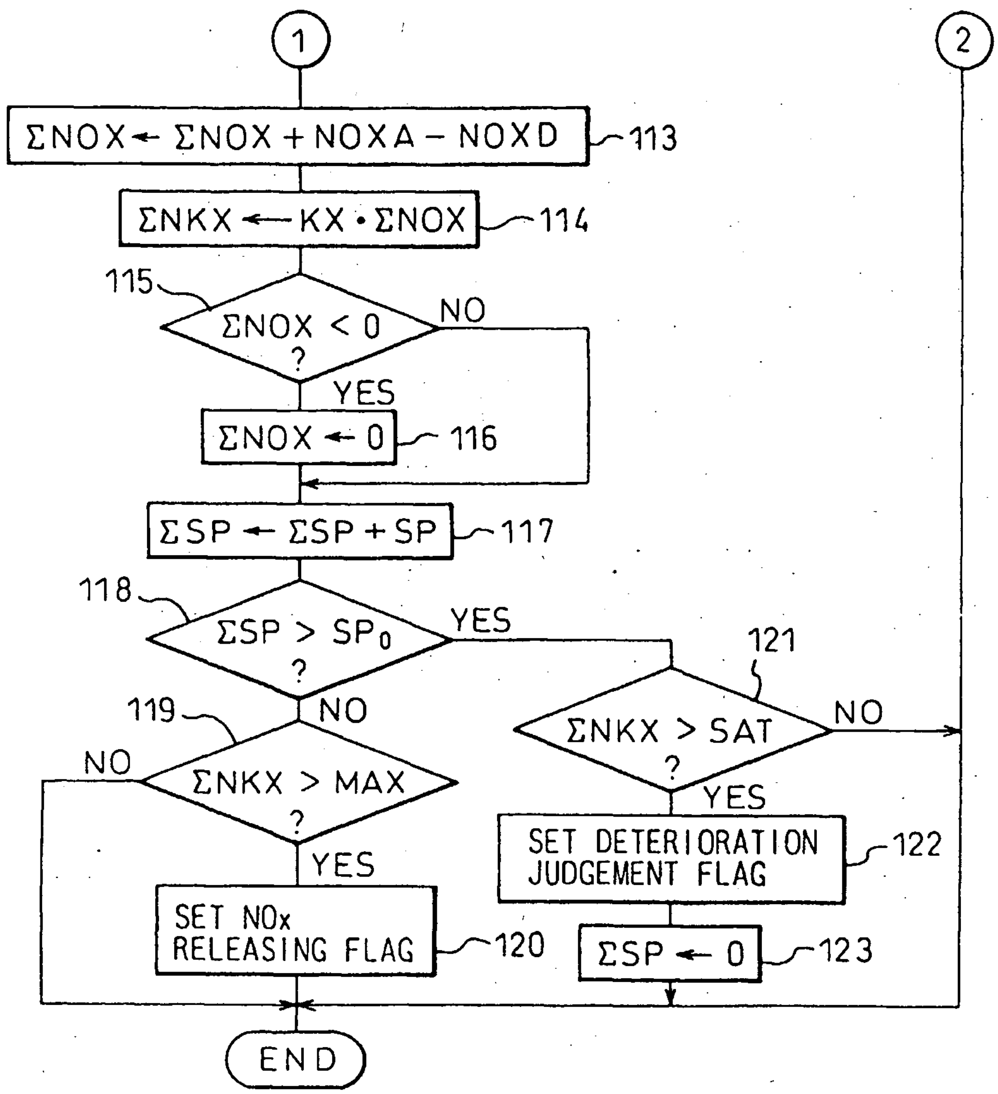

1
2
ΣNOX ← ΣNOX + NOXA − NOXD
113
ΣNKX ← KX • ΣNOX
114
115
ΣNOX < 0 ?
NO
YES
ΣNOX ← 0
116
ΣSP ← ΣSP + SP
117
118
ΣSP > SP0 ?
YES
121
NO
119
ΣNKX > SAT ?
NO
NO
ΣNKX > MAX ?
YES
SET DETERIORATION JUDGEMENT FLAG
122
YES
SET NOx RELEASING FLAG
120
ΣSP ← 0
123
END

Fig.14

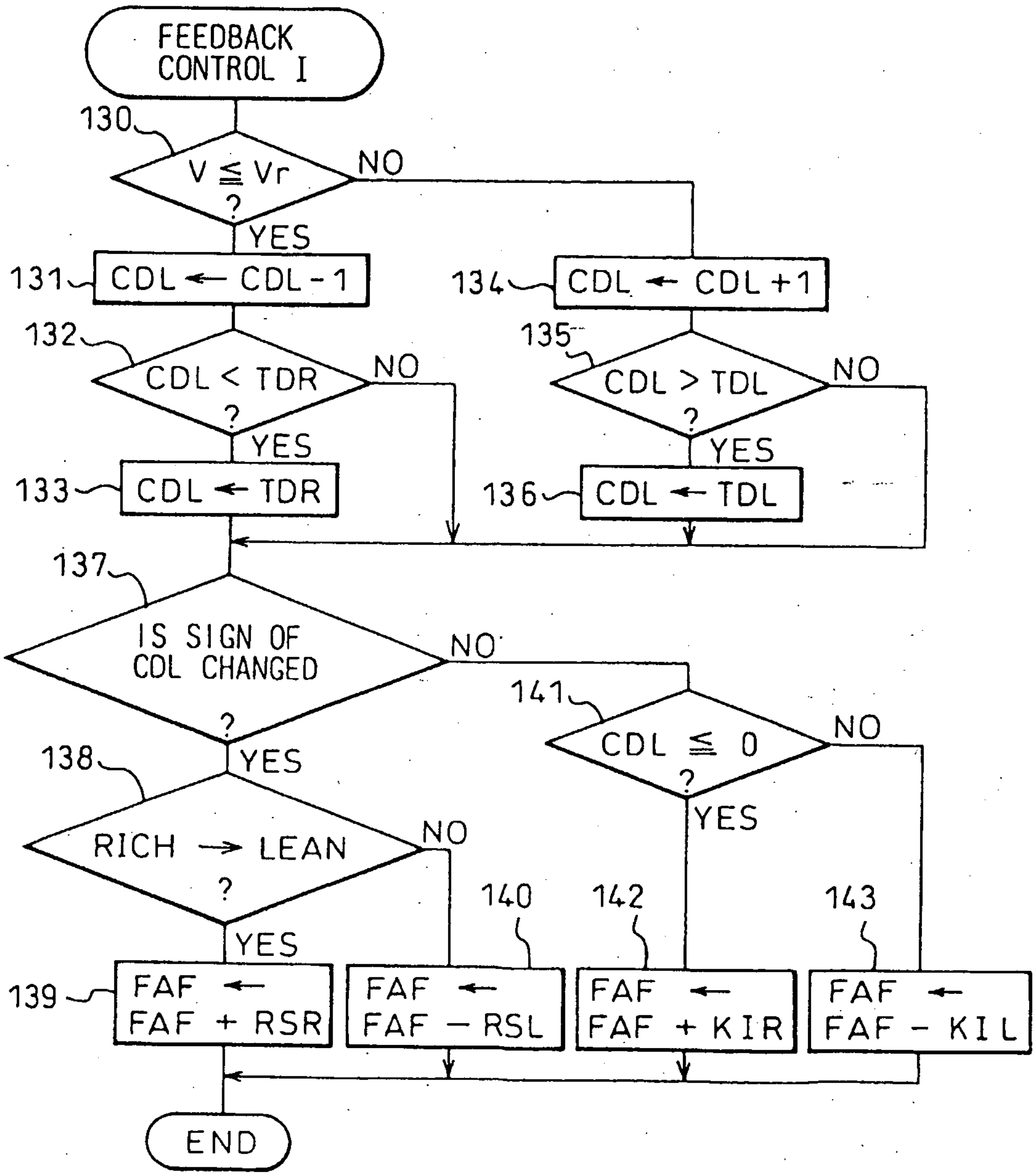

FEEDBACK CONTROL I
130
V ≦ Vr ?
NO
YES
131
CDL ← CDL - 1
134
CDL ← CDL + 1
132
CDL < TDR ?
NO
YES
135
CDL > TDL ?
NO
YES
133
CDL ← TDR
136
CDL ← TDL
137
IS SIGN OF CDL CHANGED ?
NO
141
CDL ≦ 0 ?
NO
YES
138
YES
RICH → LEAN ?
NO
YES
140
142
143
139
FAF ← FAF + RSR
FAF ← FAF − RSL
FAF ← FAF + KIR
FAF ← FAF − KIL
END

Fig.15

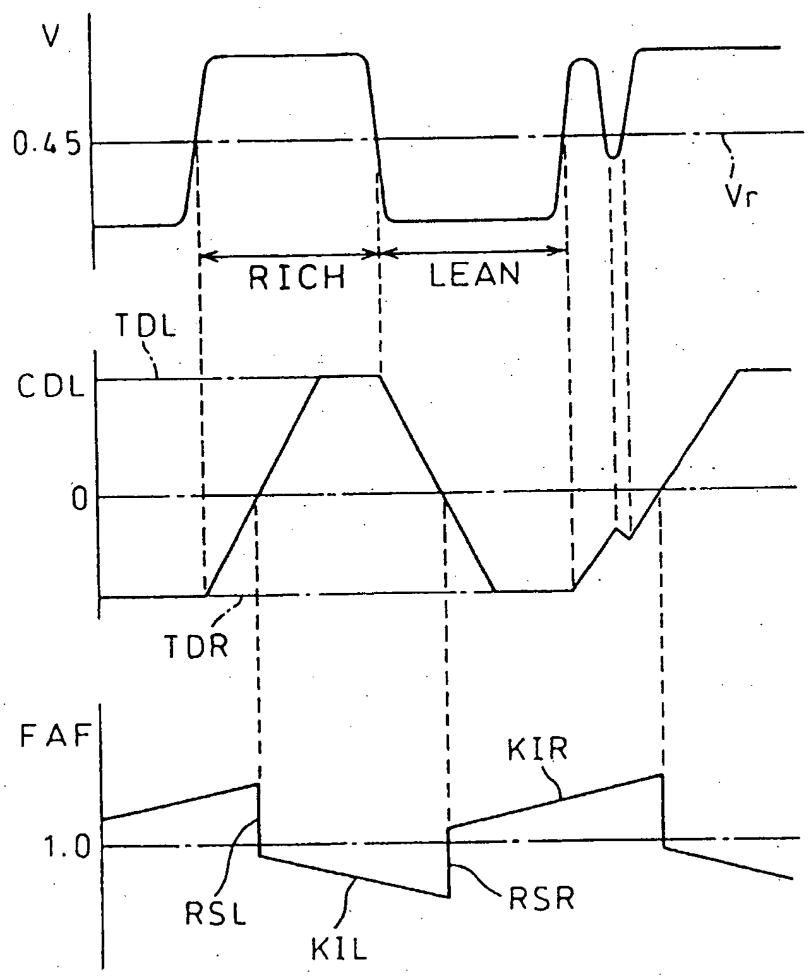


Fig.16

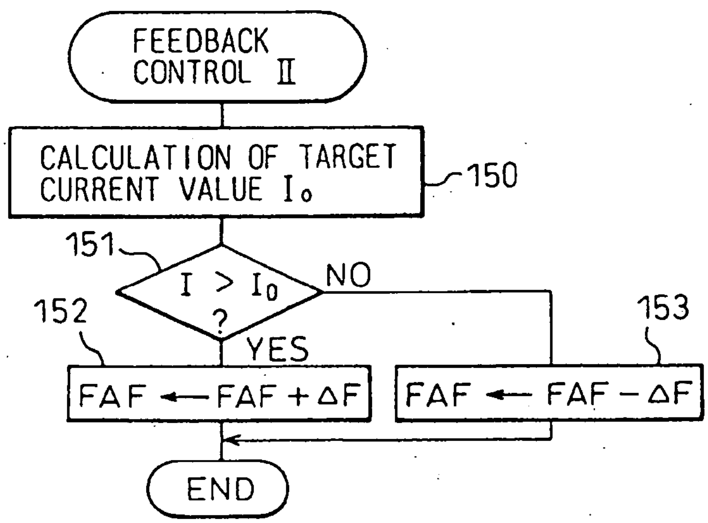

FEEDBACK CONTROL II
CALCULATION OF TARGET CURRENT VALUE I_0
150
151
$I > I_0$?
NO
YES
152
153
FAF ← FAF + ΔF
FAF ← FAF − ΔF
END

Fig.17

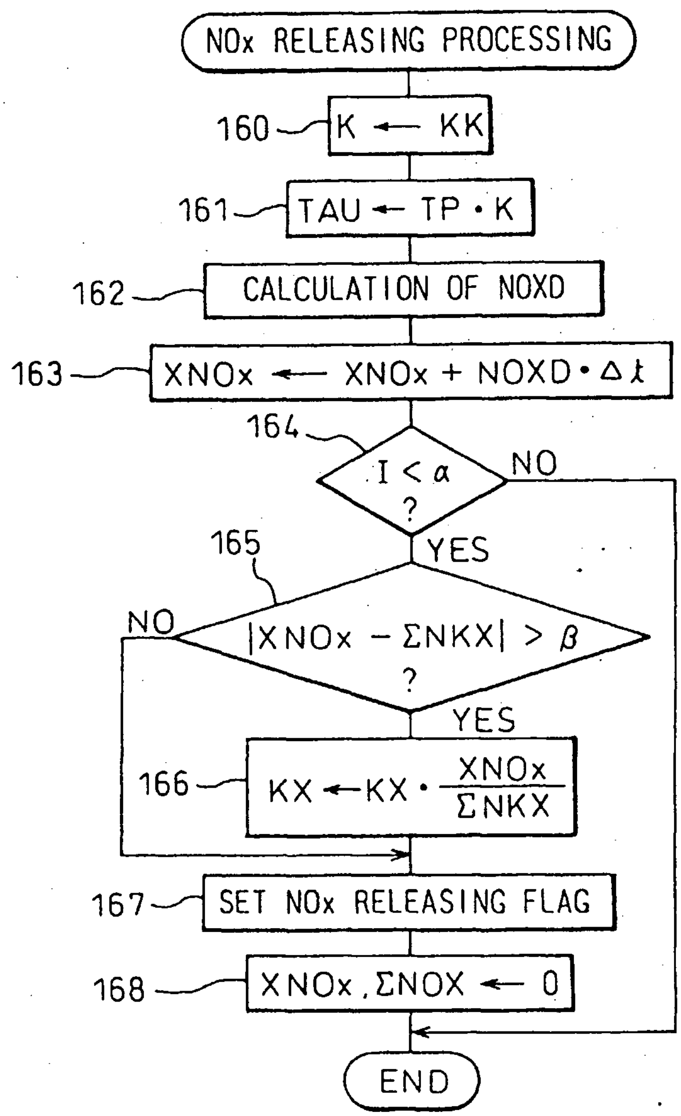

NOx RELEASING PROCESSING
160
K ← KK
161
TAU ← TP • K
162
CALCULATION OF NOXD
163
XNOx ← XNOx + NOXD • Δt
164
I < α ?
NO
YES
165
|XNOx − ΣNKX| > β ?
NO
YES
166
KX ← KX • XNOx / ΣNKX
167
SET NOx RELEASING FLAG
168
XNOx, ΣNOX ← 0
END

Fig.18

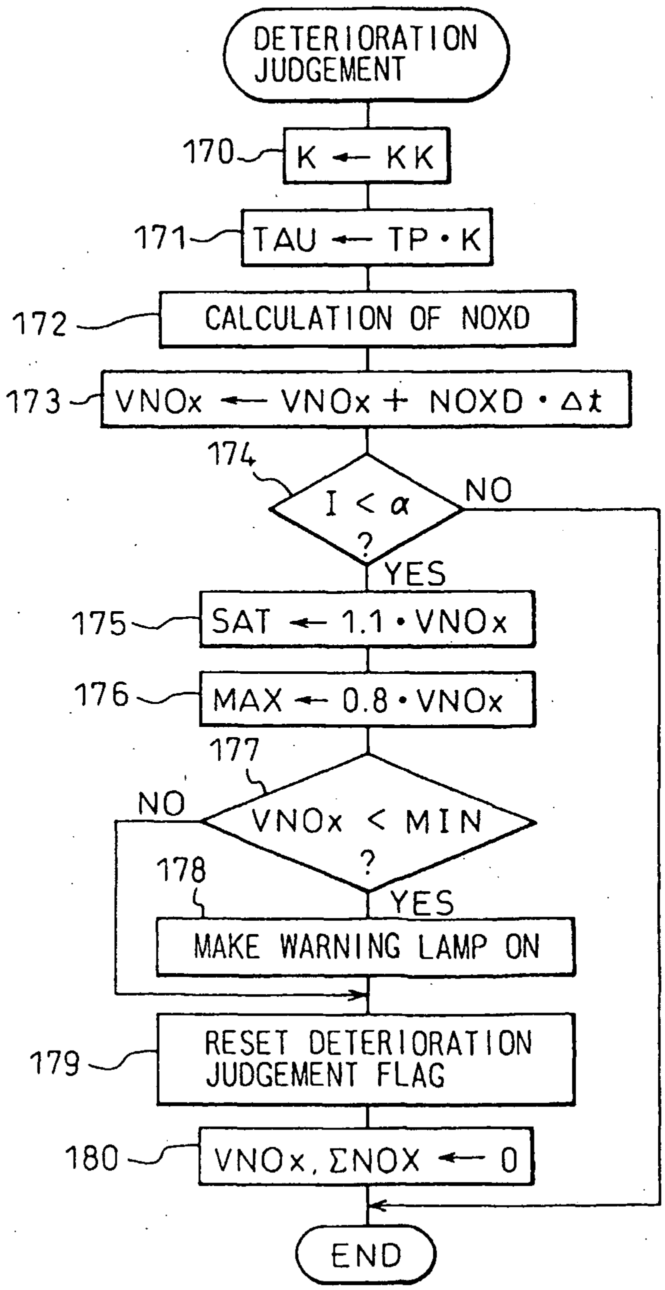

DETERIORATION JUDGEMENT
170
K ← KK
171
TAU ← TP • K
172
CALCULATION OF NOXD
173
VNOx ← VNOx + NOXD • Δt
174
I < α ?
NO
YES
175
SAT ← 1.1 • VNOx
176
MAX ← 0.8 • VNOx
177
VNOx < MIN ?
NO
YES
178
MAKE WARNING LAMP ON
179
RESET DETERIORATION JUDGEMENT FLAG
180
VNOx, ΣNOX ← 0
END

Fig.19A

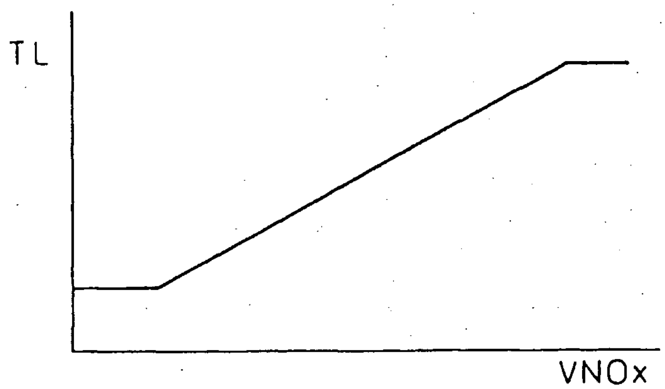


Fig.19B

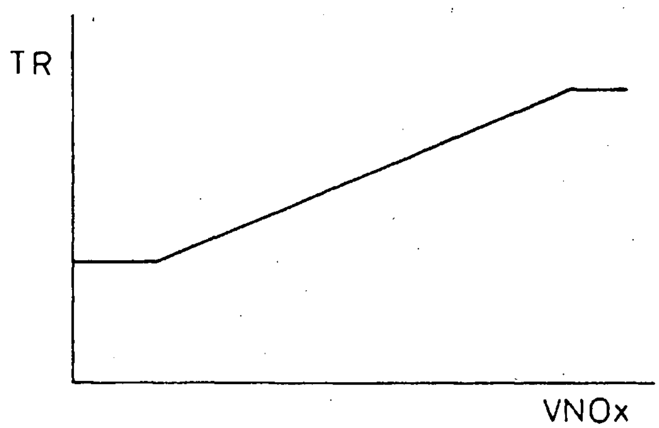


Fig. 20

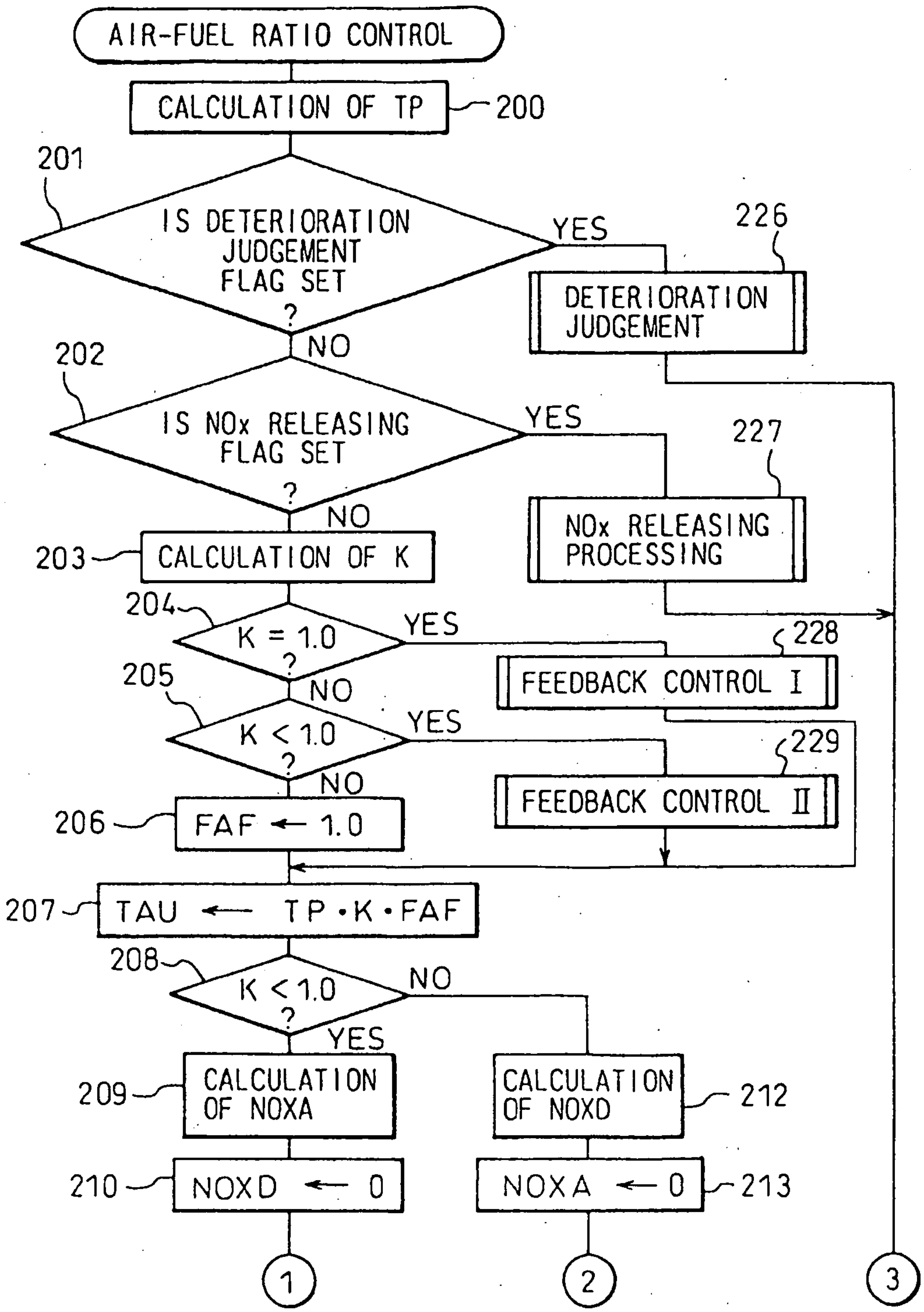
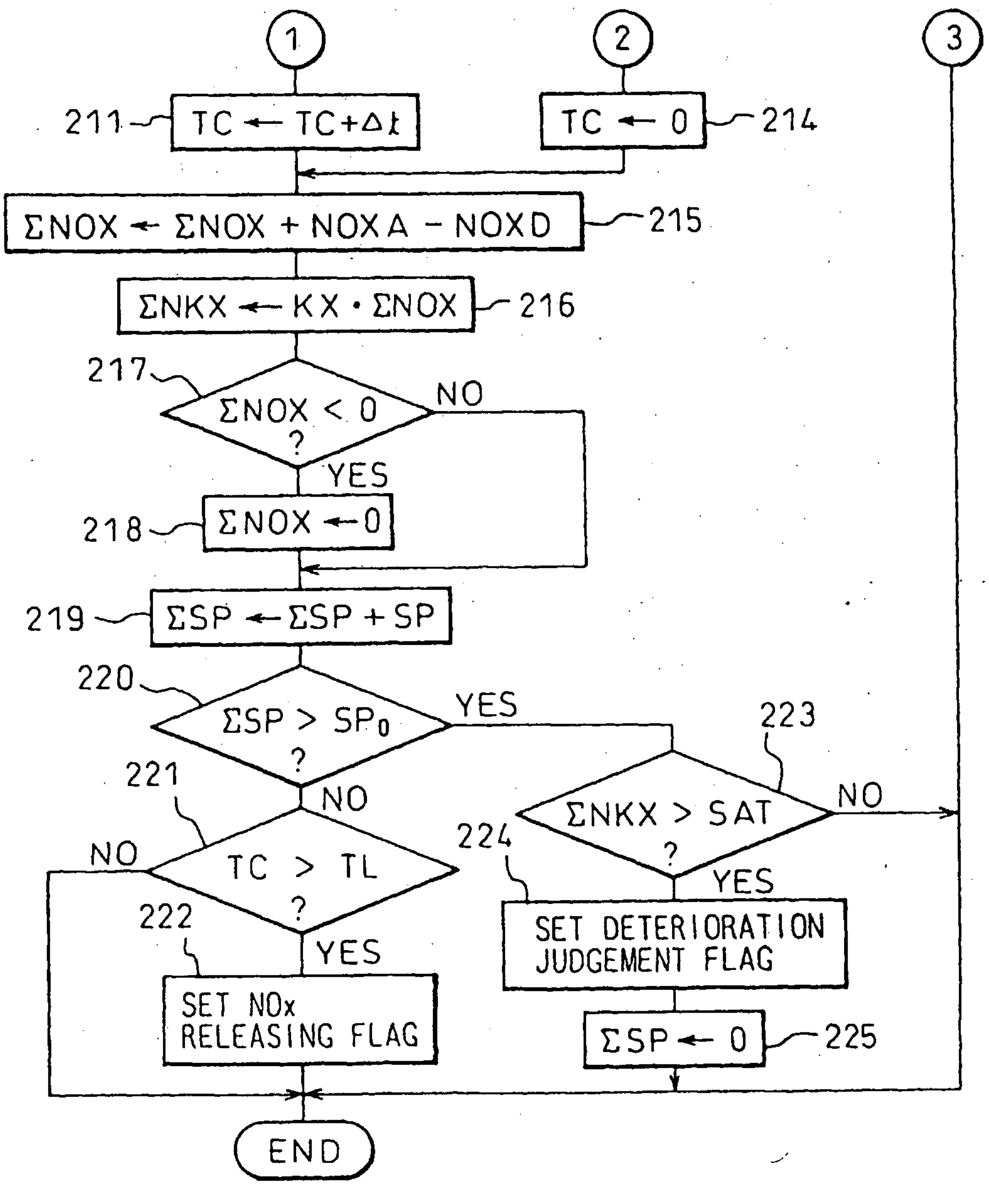

AIR-FUEL RATIO CONTROL
CALCULATION OF TP
200
201
IS DETERIORATION JUDGEMENT FLAG SET ?
YES
226
DETERIORATION JUDGEMENT
NO
202
IS NOx RELEASING FLAG SET ?
YES
227
NOx RELEASING PROCESSING
NO
203
CALCULATION OF K
204
K = 1.0 ?
YES
228
FEEDBACK CONTROL I
NO
205
K < 1.0 ?
YES
229
FEEDBACK CONTROL II
NO
206
FAF ← 1.0
207
TAU ← TP・K・FAF
208
K < 1.0 ?
NO
YES
209
CALCULATION OF NOXA
212
CALCULATION OF NOXD
210
NOXD ← 0
NOXA ← 0
213
1
2
3

Fig.21



1
2
3
211
TC ← TC+Δt
TC ← 0
214
ΣNOX ← ΣNOX + NOXA − NOXD
215
ΣNKX ← KX · ΣNOX
216
217
ΣNOX < 0 ?
NO
YES
218
ΣNOX ← 0
219
ΣSP ← ΣSP + SP
220
ΣSP > SP0 ?
YES
223
221
NO
ΣNKX > SAT ?
NO
224
NO
TC > TL ?
YES
222
YES
SET DETERIORATION JUDGEMENT FLAG
SET NOx RELEASING FLAG
ΣSP ← 0
225
END

Fig. 22

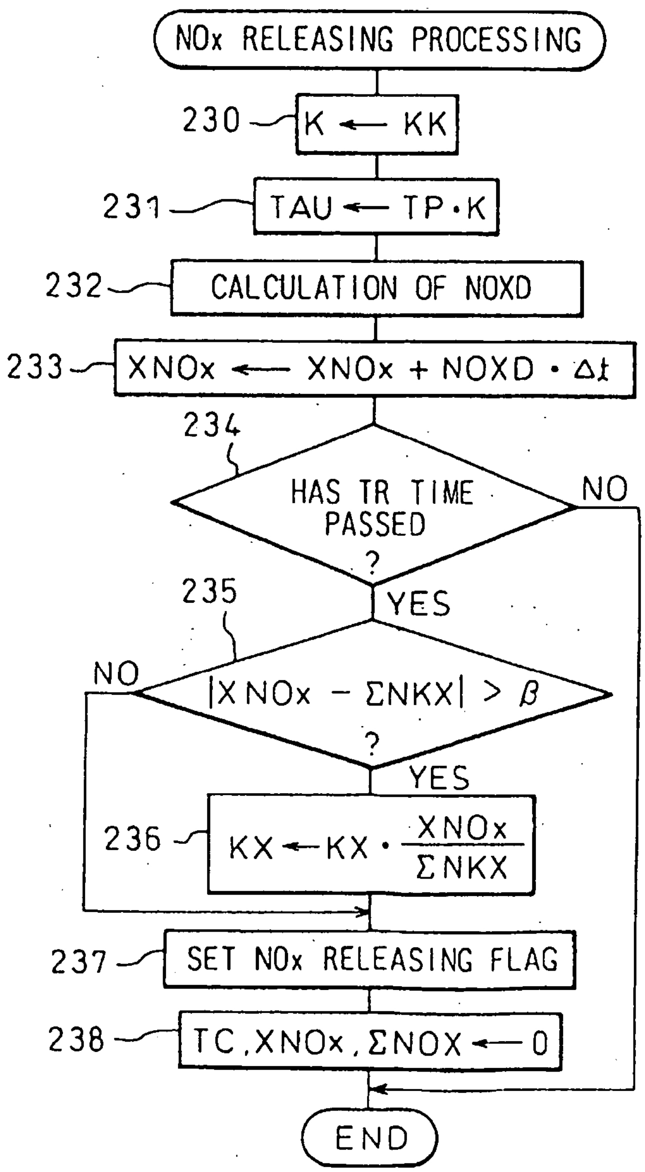
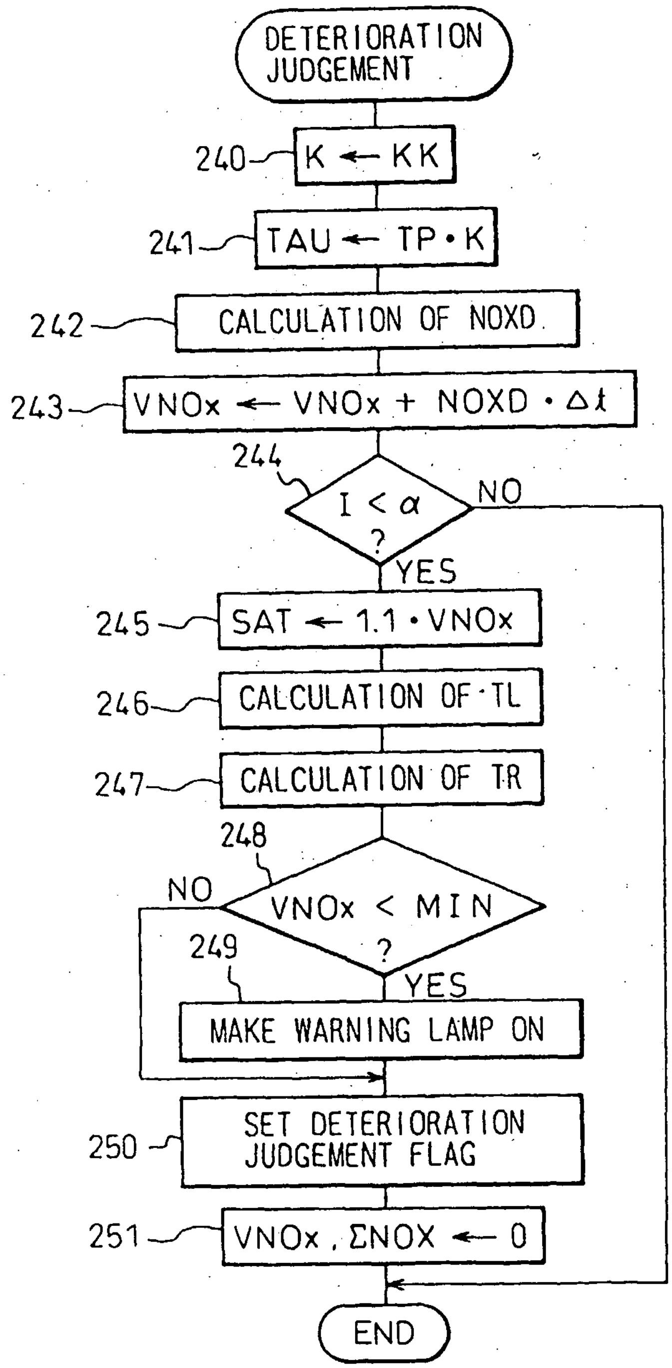

NOx RELEASING PROCESSING
230
K ← KK
231
TAU ← TP・K
232
CALCULATION OF NOXD
233
XNOx ← XNOx + NOXD・Δt
234
HAS TR TIME PASSED ?
NO
YES
235
|XNOx − ΣNKX| > β ?
NO
YES
236
KX ← KX・XNOx / ΣNKX
237
SET NOx RELEASING FLAG
238
TC, XNOx, ΣNOX ← 0
END

Fig.23


DETERIORATION JUDGEMENT
240
K ← KK
241
TAU ← TP • K
242
CALCULATION OF NOXD
243
VNOx ← VNOx + NOXD • Δt
244
I < α ?
NO
YES
245
SAT ← 1.1 • VNOx
246
CALCULATION OF TL
247
CALCULATION OF TR
248
VNOx < MIN ?
NO
YES
249
MAKE WARNING LAMP ON
250
SET DETERIORATION JUDGEMENT FLAG
251
VNOx , ΣNOX ← 0
END